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(21) International Application Number: PCT/GB97/02954 (22) International Filing Date: 28 October 1997 (28.10.97) (30) Priority Data: <table border="0"> <tr> <td>9622368.0</td> <td>28 October 1996 (28.10.96)</td> <td>GB</td> </tr> <tr> <td>9622367.2</td> <td>28 October 1996 (28.10.96)</td> <td>GB</td> </tr> <tr> <td>9622366.4</td> <td>28 October 1996 (28.10.96)</td> <td>GB</td> </tr> <tr> <td>9700699.3</td> <td>15 January 1997 (15.01.97)</td> <td>GB</td> </tr> <tr> <td>9708265.5</td> <td>24 April 1997 (24.04.97)</td> <td>GB</td> </tr> <tr> <td>9711846.7</td> <td>6 June 1997 (06.06.97)</td> <td>GB</td> </tr> <tr> <td>9711842.6</td> <td>6 June 1997 (06.06.97)</td> <td>GB</td> </tr> </table> (71) Applicant (for GB only): MARSDEN, John, Christopher [GB/GB]; Frank B. Dehn & Co., 179 Queen Victoria Street, London EC4V 4EL (GB). (71) Applicant (for all designated States except US): NYCOMED IMAGING AS [NO/NO]; Nycoveien 2, P.O. Box 4220 Torshov, N-0401 Oslo (NO). (72) Inventors; and (75) Inventors/Applicants (for US only): KLAVENESS, Jo [NO/NO]; Midtåsen 5, N-1166 Oslo (NO). RONGVED, Pål [NO/NO]; Nycomed Imaging AS, Nycoveien 2, P.O. Box 4220 Torshov, N-0401 Oslo (NO). HØGSET,		9622368.0	28 October 1996 (28.10.96)	GB	9622367.2	28 October 1996 (28.10.96)	GB	9622366.4	28 October 1996 (28.10.96)	GB	9700699.3	15 January 1997 (15.01.97)	GB	9708265.5	24 April 1997 (24.04.97)	GB	9711846.7	6 June 1997 (06.06.97)	GB	9711842.6	6 June 1997 (06.06.97)	GB	Anders [NO/NO]; Treskevn. 32A, N-0681 Oslo (NO). TOLLESHAUG, Helge [NO/NO]; Nycomed Imaging AS, Nycoveien 2, P.O. Box 4220 Torshov, N-0401 Oslo (NO). NÆVESTAD, Anne [NO/NO]; Tamburveien 13K, N-0485 Oslo (NO). HELLEBUST, Halldis [NO/NO]; Olaf Bulls v.36, N-0765 Oslo (NO). HOFF, Lars [NO/NO]; Åsengata 29, N-0480 Oslo (NO). CUTHBERTSON, Alan [GB/NO]; Nycomed Imaging AS, Nycoveien 2, P.O. Box 4220 Torshov, N-0401 Oslo (NO). LØVHAUG, Dagfinn [NO/NO]; Nycomed Imaging AS, Nycoveien 2, P.O. Box 4220 Torshov, N-0401 Oslo (NO). SOLBAKKEN, Magne [NO/NO]; Nycomed Imaging AS, Nycoveien 2, P.O. Box 4220 Torshov, N-0401 Oslo (NO). (74) Agent: MARSDEN, John, Christopher; Frank B. Dehn & Co., 179 Queen Victoria Street, London EC4V 4EL (GB). (81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG). Published <i>Without international search report and to be republished upon receipt of that report.</i>
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(54) Title: IMPROVEMENTS IN OR RELATING TO DIAGNOSTIC/THERAPEUTIC AGENTS (57) Abstract Targetable diagnostic and/or therapeutically active agents, e.g. ultrasound contrast agents, having reporters comprising gas-filled microbubbles stabilised by monolayers of film-forming surfactants, the reporter being coupled or linked to at least one vector.																							

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Improvements in or relating to diagnostic/therapeutic agents

5 This invention relates to diagnostic and/or therapeutically active agents, more particularly to diagnostic and/or therapeutically active agents incorporating moieties which interact with or have affinity for sites and/or structures within the body so
10 that diagnostic imaging and/or therapy of particular locations within the body may be enhanced. Of particular interest are diagnostic agents for use in ultrasound imaging, which are hereinafter referred to as targeted ultrasound contrast agents.

15 It is well known that ultrasound imaging comprises a potentially valuable diagnostic tool, for example in studies of the vascular system, particularly in cardiography, and of tissue microvasculature. A variety of contrast agents has been proposed to enhance the
20 acoustic images so obtained, including suspensions of solid particles, emulsified liquid droplets, gas bubbles and encapsulated gases or liquids. It is generally accepted that low density contrast agents which are easily compressible are particularly efficient in terms
25 of the acoustic backscatter they generate, and considerable interest has therefore been shown in the preparation of gas-containing and gas-generating systems.

 Gas-containing contrast media are also known to be
30 effective in magnetic resonance (MR) imaging, e.g. as susceptibility contrast agents which will act to reduce MR signal intensity. Oxygen-containing contrast media also represent potentially useful paramagnetic MR contrast agents.

35 Furthermore, in the field of X-ray imaging it has been observed that gases such as carbon dioxide may be used as negative oral contrast agents or intravascular

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contrast agents.

5 The use of radioactive gases, e.g. radioactive isotopes of inert gases such as xenon, has also been proposed in scintigraphy, for example for blood pool imaging.

10 Targeted ultrasound contrast agents may be regarded as comprising (i) a reporter moiety capable of interacting with ultrasound irradiation to generate a detectable signal; (ii) one or more vectors having affinity for particular target sites and/or structures within the body, e.g. for specific cells or areas of pathology; and (iii) one or more linkers connecting said reporter and vector(s), in the event that these are not directly joined.

15 The molecules and/or structure to which the agent is intended to bind will hereinafter be referred to as the target. In order to obtain specific imaging of or a therapeutic effect at a selected region/structure in the body the target must be present and available in this region/structure. Ideally it will be expressed only in the region of interest, but usually will also be present at other locations in the body, creating possible background problems. The target may either be a defined molecular species (i.e. a target molecule) or an unknown molecule or more complex structure (i.e. a target structure) which is present in the area to be imaged and/or treated, and is able to bind specifically or selectively to a given vector molecule.

20 The vector is attached or linked to the reporter moiety in order to bind these moieties to the region/structure to be imaged and/or treated. The vector may bind specifically to a chosen target, or it may bind only selectively, having affinity also for a limited number of other molecules/structures, again creating possible background problems.

35 There is a limited body of prior art relating to targeted ultrasound contrast agents. Thus, for example,

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US-A-5531980 is directed to systems in which the reporter comprises an aqueous suspension of air or gas microbubbles stabilised by one or more film-forming surfactants present at least partially in lamellar or laminar form, said surfactant(s) being bound to one or more vectors comprising "bioactive species designed for specific targeting purposes". It is stated that the microbubbles are not directly encapsulated by surfactant material but rather that this is incorporated in liquid-filled liposomes which stabilise the microbubbles. It will be appreciated that lamellar or laminar surfactant material such as phospholipids present in such liposomes will inevitably be present in the form of one or more lipid bilayers with the lipophilic tails "back-to-back" and the hydrophilic heads both inside and outside (see e.g. Schneider, M. on "Liposomes as drug carriers: 10 years of research" in *Drug targeting, Nyon, Switzerland, 3-5 October 1984*, Buri, P. and Gumma, A. (Ed), Elsevier, Amsterdam 1984).

EP-A-0727225 describes targeted ultrasound contrast agents in which the reporter comprises a chemical having a sufficient vapour pressure such that a proportion of it is a gas at the body temperature of the subject. This chemical is associated with a surfactant or albumin carrier which includes a protein-, peptide- or carbohydrate-based cell adhesion molecule ligand as vector. The reporter moieties in such contrast agents correspond to the phase shift colloid systems described in WO-A-9416739; it is now recognised that administration of such phase shift colloids may lead to generation of microbubbles which grow uncontrollably, possibly to the extent where they cause potentially dangerous embolisation of, for example, the myocardial vasculature and brain (see e.g. Schwarz, *Advances in Echo-Contrast [1994(3)]*, pp 48-49).

WO-A-9320802 proposes that tissue-specific ultrasonic image enhancement may be achieved using

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acoustically reflective oligolamellar liposomes conjugated to tissue-specific ligands such as antibodies, peptides, lectins etc. The liposomes are deliberately chosen to be devoid of gas and so will not have the advantageous echogenic properties of gas-based ultrasound contrast agents. Further references to this technology, e.g. in targeting to fibrin, thrombi and atherosclerotic areas are found in publications by Alkanonyuksel, H. et al. in *J. Pharm. Sci.* (1996) 85(5), 486-490; *J. Am. Coll. Cardiol.* (1996) 27(2) Suppl A, 298A; and *Circulation*, 68 Sci. Sessions, Anaheim 13-16 November 1995.

There is also a number of publications concerning ultrasound contrast agents which refer in passing to possible use of monoclonal antibodies as vectors without giving significant practical detail and/or to reporters comprising materials which may be taken up by the reticuloendothelial system and thereby permit image enhancement of organs such as the liver - see, for example WO-A-9300933, WO-A-9401140, WO-A-9408627, WO-A-9428874, US-A-5088499, US-A-5348016 and US-A-5469854.

The present invention is based on the finding that gas-filled microbubbles stabilised by monolayers of film-forming surfactant material are particularly useful reporters in targeted diagnostic and/or therapeutic agents. Thus, for example, the flexibility and deformability of such thin monolayer membranes substantially enhances the echogenicity of such reporters relative to liposome systems containing lipid bilayers or multiples of such bilayers. This may permit the use of very low doses of the reporter material to achieve high ultrasound contrast efficacy, with consequent safety benefits.

Thus according to one aspect of the present invention there is provided a targetable diagnostic and/or therapeutically active agent, e.g. an ultrasound contrast agent, comprising a suspension in an aqueous

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carrier liquid, e.g. an injectable carrier liquid, of a reporter comprising gas-filled microbubbles stabilised by monolayers of film-forming surfactant material, said agent further comprising at least one vector.

5 The term "monolayer" is used herein to denote that the amphiphilic surfactant moieties form monolayer films or membranes similar to so-called Langmuir-Blodgett films at the gas-liquid interfaces, with the lipophilic parts of the amphiphiles aligning towards the gas phase
10 and the hydrophilic parts interacting with the water phase.

 As indicated in WO-A-9729783, it is believed that electrostatic repulsion between charged phospholipid membranes encourages the formation of stable and
15 stabilising monolayers at microbubble-carrier liquid interfaces. The flexibility and deformability of such thin membranes are believed to enhance the echogenicity of products according to the invention disclosed therein relative to gas-filled liposomes comprising one or more
20 lipid bilayers. The amount of phospholipid used to stabilise such microbubble-containing aqueous suspensions may be as low as that necessary for formation of single monolayers of surfactant around each gas microbubble, the resulting film-like structure
25 stabilising the microbubbles against collapse or coalescence. Microbubbles with a liposome-like surfactant bilayer are believed not to be obtained when such low phospholipid concentrations are used.

 One advantageous embodiment of the invention is
30 based on the additional finding that limited adhesion to targets is a highly useful property of diagnostic and/or therapeutically active agents, which property may be achieved using vectors giving temporary retention rather than fixed adhesion to a target. Thus such agents,
35 rather than being fixedly retained at specific sites, may for example effectively exhibit a form of retarded flow along the vascular endothelium by virtue of their

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transient interactions with endothelial cells. Such agents may thus become concentrated on the walls of blood vessels, in the case of ultrasound contrast agents providing enhanced echogenicity thereof relative to the bulk of the bloodstream, which is devoid of anatomical features. They therefore may permit enhanced imaging of the capillary system, including the microvasculature, and so may facilitate distinction between normal and inadequately perfused tissue, e.g. in the heart, and may also be useful in visualising structures such as Kupffer cells, thrombi and atherosclerotic lesions or for visualising neo-vascularised and inflamed tissue areas. The present invention is particularly suited to imaging changes which occur in normal blood vessels situated in areas of tissue necrosis.

In a further embodiment of the present invention, one or more vectors may be attached to or included within the reporter in a manner such that the vectors are not readily exposed to the target or target receptors. Increased tissue specificity may therefore be achieved by applying an additional process to expose the vectors, for example by exposing the agent after administration to external ultrasound so as to modify the diffusibility of the moieties containing the vectors.

Any biocompatible gas may be present in the reporter, the term "gas" as used herein including any substances (including mixtures) substantially or completely in gaseous (including vapour) form at the normal human body temperature of 37°C. The gas may thus, for example, comprise air; nitrogen; oxygen; carbon dioxide; hydrogen; an inert gas such as helium, argon, xenon or krypton; a sulphur fluoride such as sulphur hexafluoride, disulphur decafluoride or trifluoromethylsulphur pentafluoride; selenium hexafluoride; an optionally halogenated silane such as methylsilane or dimethylsilane; a low molecular weight

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hydrocarbon (e.g. containing up to 7 carbon atoms), for example an alkane such as methane, ethane, a propane, a butane or a pentane, a cycloalkane such as cyclopropane, cyclobutane or cyclopentane, an alkene such as ethylene, propene, propadiene or a butene, or an alkyne such as acetylene or propyne; an ether such as dimethyl ether; a ketone; an ester; a halogenated low molecular weight hydrocarbon (e.g. containing up to 7 carbon atoms); or a mixture of any of the foregoing. Advantageously at least some of the halogen atoms in halogenated gases are fluorine atoms; thus biocompatible halogenated hydrocarbon gases may, for example, be selected from bromochlorodifluoromethane, chlorodifluoromethane, dichlorodifluoromethane, bromotrifluoromethane, chlorotrifluoromethane, chloropentafluoroethane, dichlorotetrafluoroethane, chlorotrifluoroethylene, fluoroethylene, ethylfluoride, 1,1-difluoroethane and perfluorocarbons, e.g. perfluoroalkanes such as perfluoromethane, perfluoroethane, perfluoropropanes, perfluorobutanes (e.g. perfluoro-n-butane, optionally in admixture with other isomers such as perfluoro-isobutane), perfluoropentanes, perfluorohexanes and perfluoroheptanes; perfluoroalkenes such as perfluoropropene, perfluorobutenes (e.g. perfluorobut-2-ene) and perfluorobutadiene; perfluoroalkynes such as perfluorobut-2-yne; and perfluorocycloalkanes such as perfluorocyclobutane, perfluoromethylcyclobutane, perfluorodimethylcyclobutanes, perfluorotrimethylcyclobutanes, perfluorocyclopentane, perfluoromethylcyclopentane, perfluorodimethylcyclopentanes, perfluorocyclohexane, perfluoromethylcyclohexane and perfluorocycloheptane. Other halogenated gases include methyl chloride, fluorinated (e.g. perfluorinated) ketones such as perfluoroacetone and fluorinated (e.g. perfluorinated) ethers such as perfluorodiethyl ether. The use of perfluorinated gases, for example sulphur hexafluoride and perfluorocarbons such as

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perfluoropropane, perfluorobutanes and perfluoropentanes, may be particularly advantageous in view of the recognised high stability in the bloodstream of microbubbles containing such gases.

5 The gas may comprise a substance such as butane, cyclobutane, n-pentane, isopentane, neopentane, cyclopentane, perfluoropentane, perfluorocyclopentane, perfluorohexane or a mixture containing one or more such gases which is liquid at handling or processing
10 temperatures but gaseous at body temperature, e.g. as described in the aforementioned WO-A-9416739, since the film-forming surfactant monolayers in reporter units according to the invention may stabilise the resulting microbubbles against uncontrollable growth.

15 In principle, any appropriate film-forming surfactant may be employed to form the gas-encapsulating monolayers, including non-polymeric and non-polymerisable wall-forming surfactant materials, e.g. as described in WO-A-9521631; polymer surfactant material,
20 e.g. as described in WO-A-9506518; and phospholipids, e.g. as described in WO-A-9211873, WO-A-9217212, WO-A-9222247, WO-A-9428780, WO-A-9503835 or WO-A-9729783. Advantageously 75%, preferably substantially all, of the film-forming surfactant present in agents according to
25 the invention is incorporated into monolayers at the gas-liquid interfaces.

 Representative examples of useful phospholipids include lecithins (i.e. phosphatidylcholines), for example natural lecithins such as egg yolk lecithin or
30 soya bean lecithin and synthetic or semisynthetic lecithins such as dimyristoylphosphatidylcholine, dipalmitoylphosphatidylcholine or distearoylphosphatidylcholine; phosphatidic acids; phosphatidylethanolamines; phosphatidylserines;
35 phosphatidylglycerols; phosphatidylinositols; cardiolipins; sphingomyelins; fluorinated analogues of any of the foregoing; mixtures of any of the foregoing

and mixtures with other lipids such as cholesterol.

It has been found that the use of phospholipids predominantly (e.g. at least 75%) comprising molecules individually bearing net overall charge may be particularly advantageous, especially when used as essentially the sole amphiphilic component of the reporter, and may convey valuable benefits in terms of parameters such as product stability and acoustic properties. Without wishing to be bound by theoretical considerations, it is believed that electrostatic repulsion between charged phospholipid membranes may encourage the formation of stable monolayers at the gas-liquid interfaces; as noted above, the flexibility and deformability of such thin membranes will enhance the echogenicity of reporters used in accordance with the invention relative to gas-filled liposomes comprising one or more lipid bilayers.

The use of charged phospholipids may also provide reporters with advantageous properties regarding, for example, stability, dispersibility and resistance to coalescence without recourse to additives such as further surfactants and/or viscosity enhancers, thereby ensuring that the number of components administered to the body of a subject upon injection of the contrast agents is kept to a minimum. Thus, for example, the charged surfaces of the microbubbles may minimise or prevent their aggregation as a result of electrostatic repulsion.

Desirably at least 75%, preferably substantially all of phospholipid material used in reporters in agents of the invention consists of molecules bearing a net overall charge under conditions of preparation and/or use, which charge may be positive or, more preferably, negative. Representative positively charged phospholipids include esters of phosphatidic acids such as dipalmitoylphosphatidic acid or distearoylphosphatidic acid with aminoalcohols such as

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hydroxyethylethylenediamine. Examples of negatively charged phospholipids include naturally occurring (e.g. soya bean or egg yolk derived), semisynthetic (e.g. partially or fully hydrogenated) and synthetic
5 phosphatidylserines, phosphatidylglycerols, phosphatidylinositols, phosphatidic acids and cardiolipins. The fatty acyl groups of such phospholipids will typically each contain about 14-22 carbon atoms, for example as in palmitoyl and stearoyl
10 groups. Lyso forms of such charged phospholipids are also useful in accordance with the invention, the term "lyso" denoting phospholipids containing only one fatty acyl group, this preferably being ester-linked to the 1-position carbon atom of the glyceryl moiety. Such lyso
15 forms of charged phospholipids may advantageously be used in admixture with charged phospholipids containing two fatty acyl groups.

Phosphatidylserines represent particularly preferred phospholipids of use in agents according to
20 the invention and preferably constitute a substantial part, e.g. at least 80% of the phospholipid content thereof, for example 85-92%. While we do not wish to be bound by theoretical considerations, it may be that ionic bridging between the carboxyl and amino groups of
25 adjacent serine moieties contributes to the stability of such reporter systems. Preferred phosphatidylserines include saturated (e.g. hydrogenated or synthetic) natural phosphatidylserine and synthetic distearoylphosphatidylserine, dipalmitoylphosphatidyl-
30 serine and diarachidoylphosphatidylserine.

Other potentially useful lipids include phosphatidylethanolamines optionally admixed with one or more lipids such as stearic acid, palmitic acid, stearylamine, palmitylamine, cholesterol, bisalkyl
35 glycerols, sphingoglycolipids, synthetic lipids such as N,N-dimethyl-N-octadecyl-1-octadecan ammonium chloride or bromide (DODAC, DODAB), and/or maleic acid

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bisalkylesters.

Additional exemplary lipids which may be used to prepare gas-containing contrast agents include fatty acids, stearic acid, palmitic acid, 2-n-hexadecylstearic acid, oleic acid and other acid-containing lipid structures. Such lipid structures may be coupled by amide bond formation to amino acids containing one or more amino groups; the resulting lipid-modified amino acids (e.g. dipalmitoyllysine or distearoyl-2,3-diaminopropionic acid) may be useful precursors for the attachment of functionalised spacer elements having coupling sites for conjugation of one or more vector molecules.

Further useful stabilisers include lipopeptides comprising a lipid attached to a peptide linker portion which is suitably functionalised for coupling to one or more vector molecules. A particular preference is the inclusion of a positively charged peptide linker element (e.g. comprising two or more lysine residues) capable of anchoring through electrostatic interaction with reporter microbubbles stabilised by negatively charged phospholipid or other surfactant membranes.

Another embodiment of the invention comprises functionalised microbubbles carrying one or more reactive groups for non-specific reaction with receptor molecules located on cell surfaces. Microbubbles comprising a thiol moiety, for example, may bind to cell surface receptors via disulphide exchange reactions. The reversible nature of such reactions means that microbubble flow may be controlled by altering the redox environment. Similarly, functionalised microbubbles with membranes comprising activated esters such as N-hydroxysuccinimide esters may be used to react with amino groups found on a multiplicity of cell surface molecules.

Previously proposed microbubble-containing contrast agents based on phospholipids, for example as

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described in WO-A-9409829, are typically prepared by contacting powdered surfactant, e.g. freeze-dried preformed liposomes or freeze-dried or spray-dried phospholipid solutions, with air or other gas and then
5 with aqueous carrier, agitating to generate a microbubble suspension which must then be administered shortly after its preparation. Such processes, however, suffer the disadvantages that substantial agitational energy must be imparted to generate the required
10 dispersion and that the size and size distribution of the microbubbles are dependent on the amount of energy applied and so cannot in practice be controlled.

The reporters or agents according to the present invention, on the other hand, may advantageously be
15 prepared by generating a gas microbubble dispersion in an appropriate surfactant (e.g. phospholipid)-containing aqueous medium, which may if desired previously have been autoclaved or otherwise sterilised, and then, preferably after washing and/or size fractionation of
20 the thus-formed microbubbles, subjecting the dispersion to lyophilisation, e.g. in the presence of one or more cryoprotectants/lyoprotectants, to yield a dried product which is readily reconstitutable in water/aqueous solutions to generate consistently reproducible
25 microbubble dispersions. This process is described in greater detail in WO-A-9729783, the contents of which are incorporated herein by reference; the ability to remove bubbles of unwanted size and excess surfactant material render this process of substantial advantage
30 over processes such as those described in the aforementioned WO-A-9409829 and in prior art such as WO-A-9608234 (where bubbles are generated on site prior to injection by shaking a suspension of different phospholipids and viscosity enhancers such as propylene glycol and glycerol).
35

The above-described process may be used to generate reporter microbubbles with a very narrow size

distribution, e.g. such that over 90% (e.g. at least 95%, preferably at least 98%) of the microbubbles have volume mean diameter in the range 1-7 μm and less than 5% (e.g. not more than 3%, preferably not more than 2%) of the microbubbles have volume mean diameter above 7 μm . The washing step may be used to ensure that the reporter is substantially free of unwanted components such as excess lipids or viscosity enhancers. Agents containing reporters prepared in this way may exhibit the following advantages over prior art contrast agent materials:

Echogenicity per dose may be greatly enhanced since substantially all of the surfactant material participate in stabilisation of the microbubbles as monolayers. *In vivo* ultrasound tests in dogs have shown that ultrasound contrast agents prepared as above may produce an increase in backscattered signal intensity from the myocardium of 15 dB following intravenous injection of doses as low as 0.1 μl microbubbles/kg body weight.

Safety *in vivo* is improved for the same reasons, since such agents may, for example, be administered in doses such that the amount of phospholipid injected is as low as 0.1-10 $\mu\text{g/kg}$ body weight, e.g. 1-5 $\mu\text{g/kg}$. The use of such low levels of surfactant may clearly be of substantial advantage in minimising possible toxic side effects.

The high efficacy/dose ratio is also particularly advantageous in targeting applications, since it is generally understood that rather low amounts of reporter will accumulate at sites of interest when using products comprising vectors having affinity for such sites. These preferred reporters according to the invention may therefore considerably improve contrast at sites of interest compared to known targetable ultrasound contrast agents. Their high efficacy may effectively make it possible to "see" single microbubbles using

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ultrasound, giving a sensitivity close to or potentially even higher than that of scintigraphy, which currently is probably the most useful technique in targeting, although the resolution in scintigraphic pictures is not
5 impressive.

A particular advantage of phosphatidylserine-based agents is their biocompatibility; thus no acute toxic effects such as changes in blood pressure or heart rate have been observed in animal tests on dogs injected with
10 intravenous boluses of phosphatidylserine-based contrast agents prepared as described above at doses of up to ten times a normal imaging dose.

The use of charged phospholipids may also be of advantage in that they will contain functional groups
15 such as carboxyl or amino which permit ready linking of vectors, if desired by way of linking units. It should be noted that other functional groups may also be incorporated into such systems by mixing a lipid containing a desired functional group with the film-
20 forming surfactant prior to microbubble generation.

It is generally unnecessary to incorporate additives such as emulsifying agents and/or viscosity enhancers such as are commonly employed in many existing contrast agent formulations into agents of the
25 invention. As noted above, this is of advantage in keeping to a minimum the number of components administered to the body of a subject and ensuring that the viscosity of the agents is as low as possible. Since preparation of the agents typically involves a
30 freeze drying step as discussed above, it may however be advantageous to include a cryoprotectant/lyoprotectant or bulking agent, for example an alcohol, e.g. an aliphatic alcohol such as t-butanol; a polyol such as glycerol; a carbohydrate, e.g. a sugar such as sucrose,
35 mannitol, trehalose or a cyclodextrin, or a polysaccharide such as dextran; or a polyglycol such as polyethylene glycol. The use of physiologically well-

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tolerated sugars such as sucrose is preferred.

Lyophilised dried products prepared as described above are especially readily reconstitutable in water, requiring only minimal agitation such as may, for
5 example, be provided by gentle hand-shaking for a few seconds. The size of the microbubbles so generated is consistently reproducible and is independent of the amount of agitational energy applied, in practice being determined by the size of the microbubbles formed in the
10 initial microbubble dispersion; surprisingly this size parameter is substantially maintained in the lyophilised and reconstituted product. Thus, since the size of the microbubbles in the initial dispersion may readily be controlled by process parameters such as the method,
15 speed and duration of agitation, the final microbubble size may readily be controlled.

The lyophilised dried products have also proved to be storage stable for at least several months under ambient conditions. The microbubble dispersions
20 generated upon reconstitution in water are stable for at least 8 hours, permitting considerable flexibility as to when the dried product is reconstituted prior to injection.

The high efficacy of these preferred reporters may
25 make it possible to use smaller bubbles than usual while still generating ultrasound contrast effects significantly above the minimum detection levels of current ultrasound imaging equipment. Such smaller bubbles have potential advantages such as reduced
30 clogging of vessels, longer circulation times, greater ability to reach targets, and lower accumulation in lungs or other non-target organs, and their use and agents containing them constitute further features of the invention.

35 It may also be possible to use such smaller bubbles to exploit the enhanced ultrasound contrast effects of bubble clusters. It is known from theory

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that the ultrasound contrast effect of a specific number of bubbles with total volume V in a dilute dispersion increases when the bubbles aggregate to form a larger gas phase with the same total volume V . It may
5 therefore be possible to use small bubbles which give substantially no ultrasound contrast until they are clustered (as may occur in target areas in preference to non-target sites having low densities of target
10 molecules). Small bubbles may also be designed to fuse, e.g. through interbubble binding promoted by interaction with the target, so as to enhance contrast in target areas. Intersurface crosslinking and consequent
15 clustering may also be effected if the reporter, in addition to carrying a vector leading to retention at specific sites, has unreacted linker moieties capable of reaction with functional groups on other bubbles.

Within the context of the present invention, the reporter unit will usually remain attached to the vectors. However, in one type of targeting procedure,
20 sometimes called "pre-targeting", the vector (often a monoclonal antibody) is administered alone; subsequently the reporter is administered, coupled to a moiety which is capable of specifically binding the pre-targeting
25 vector molecule (when the pre-targeting vector is an antibody, the reporter may be coupled to an immunoglobulin-binding molecule, such as protein A or an anti-immunoglobulin antibody). The advantage of this
30 protocol is that time may be allowed for elimination of the vector molecules that do not bind their targets, substantially reducing the background problems that are connected with the presence of an excess of reporter-
35 vector conjugate. Within the context of the present invention, pre-targeting with one specific vector might be envisaged, followed by reporter units that are coupled to another vector and a moiety which binds the first vector.

Again in the context of the present invention, for

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example in assessment of blood perfusion rates in targeted areas such as the myocardium, it is of interest to measure the rate at which contrast agents bound to the target are displaced or released therefrom. This may be achieved in a controlled manner by administration of an additional vector and/or other substance able to displace or release the contrast agent from its target.

Ultrasound imaging modalities which may be used in accordance with the invention include two- and three-dimensional imaging techniques such as B-mode imaging (for example using the time-varying amplitude of the signal envelope generated from the fundamental frequency of the emitted ultrasound pulse, from sub-harmonics or higher harmonics thereof or from sum or difference frequencies derived from the emitted pulse and such harmonics, images generated from the fundamental frequency or the second harmonic thereof being preferred), colour Doppler imaging and Doppler amplitude imaging, and combinations of the two latter with any of the above modalities. Surprisingly excellent second harmonic signals have been obtained from targeted monolayer-stabilised microspheres in accordance with the present invention. To reduce the effects of movement, successive images of tissues such as the heart or kidney may be collected with the aid of suitable synchronisation techniques (e.g. gating to the ECG or respiratory movement of the subject). Measurement of changes in resonance frequency or frequency absorption which accompany arrested or retarded microbubbles may also usefully be made to detect the contrast agent.

The present invention provides a tool for therapeutic drug delivery in combination with vector-mediated direction of the product to the desired site. By "therapeutic" or "drug" is meant an agent having a beneficial effect on a specific disease in a living human or non-human animal. Whilst combinations of drugs and ultrasound contrast agents have been proposed in,

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for example, WO-A-9428873 and WO-A-9507072, these products lack vectors having affinity for particular sites and thereby show comparatively poor specific retention at desired sites prior to or during drug
5 release.

Therapeutic compounds used in accordance with the present invention may be encapsulated in the interior of the microbubbles or attached to or incorporated in the stabilising membranes. Thus, the therapeutic compound
10 may be linked to a part of the membrane, for example through covalent or ionic bonds, or may be physically mixed into the stabilising material, particularly if the drug has similar polarity or solubility to the membrane material, so as to prevent it from leaking out of the
15 product before it is intended to act in the body. The release of the drug may be initiated merely by wetting contact with blood following administration or as a consequence of other internal or external influences, e.g. dissolution processes catalyzed by enzymes or the
20 use of of ultrasound. The destruction of gas-containing microparticles using external ultrasound is a well known phenomenon in respect of ultrasound contrast agents, e.g. as described in WO-A-9325241; the rate of drug release may be varied depending on the type of
25 therapeutic application, using a specific amount of ultrasound energy from the transducer.

The therapeutic may be covalently linked to the encapsulating membrane surface using a suitable linking agent, e.g. as described herein. Thus, for example, one
30 may initially prepare a phospholipid or lipopeptide derivative to which the drug is bonded through a biodegradable bond or linker, and then incorporate this derivative into the material used to prepare the reporter, as described above.

35 Representative therapeutics suitable for use in the present drug delivery compositions include any known therapeutic drugs or active analogues thereof containing

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thiol groups which may be coupled to thiol-containing microbubbles under oxidative conditions yielding disulphide groups. In combination with a vector or vectors such drug/vector-modified microbubbles may be
5 allowed to accumulate in target tissue; administration of a reducing agent such as reduced glutathione may then liberate the drug molecule from the targeted microbubble in the vicinity of the target cell, increasing the local concentration of the drug and enhancing its therapeutic
10 effect. Alternatively the composition may initially be prepared without the therapeutic, which may then be coupled to or coated on the microbubbles immediately prior to use; thus, for example, a therapeutic may be added to a suspension of microbubbles in aqueous media
15 and shaken in order to attach or adhere the therapeutic to the microbubbles.

Other drug delivery systems include vector-modified phospholipid membranes doped with lipopeptide structures comprising a poly-L-lysine or poly-D-lysine
20 chain in combination with a targeting vector. Applied to gene therapy/antisense technologies with particular emphasis on receptor-mediated drug delivery, the microbubble carrier is condensed with DNA or RNA via electrostatic interaction with the cationic polylysine.
25 This method has the advantage that the vector or vectors used for targeted delivery are not directly attached to the polylysine carrier moiety. The polylysine chain is also anchored more tightly in the microbubble membrane due to the presence of the lipid chains. The use of
30 ultrasound to increase the effectiveness of delivery is also considered useful.

Alternatively free polylysine chains are firstly modified with drug or vector molecules then condensed onto the negative surface of targeted microbubbles.

35 Representative and non-limiting examples of drugs useful in accordance with the invention include antineoplastic agents such as vincristine, vinblastine,

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vindesine, busulfan, chlorambucil, spiroplatin, cisplatin, carboplatin, methotrexate, adriamycin, mitomycin, bleomycin, cytosine arabinoside, arabinosyl adenine, mercaptopurine, mitotane, procarbazine, 5 dactinomycin (antinomycin D), daunorubicin, doxorubicin hydrochloride, taxol, plicamycin, aminoglutethimide, estramustine, flutamide, leuprolide, megestrol acetate, tamoxifen, testolactone, trilostane, amsacrine (m-AMSA), asparaginase (L-asparaginase), etoposide, interferon a- 10 2a and 2b, blood products such as hematoporphyrins or derivatives of the foregoing; biological response modifiers such as muramylpeptides; antifungal agents such as ketoconazole, nystatin, griseofulvin, flucytosine, miconazole or amphotericin B; hormones or 15 hormone analogues such as growth hormone, melanocyte stimulating hormone, estradiol, beclomethasone dipropionate, betamethasone, cortisone acetate, dexamethasone, flunisolide, hydrocortisone, methylprednisolone, paramethasone acetate, prednisolone, 20 prednisone, triamcinolone or fludrocortisone acetate; vitamins such as cyanocobalamin or retinoids; enzymes such as alkaline phosphatase or manganese superoxide dismutase; antiallergic agents such as amlexanox; inhibitors of tissue factor such as monoclonal 25 antibodies and Fab fragments thereof, synthetic peptides, nonpeptides and compounds downregulating tissue factor expression; inhibitors of platelets such as GPIa, GPIb and GPIIb-IIIa, ADP receptors, thrombin receptors, von Willebrand factor, prostaglandins, 30 aspirin, ticlopidin, clopigogrel and reopro; inhibitors of coagulation protein targets such as FIIa, FVa, FVIIa, FVIIIa, FIXa, FXa, tissue factor, heparins, hirudin, hirulog, argatroban, DEGR-rFVIIa and annexin V: inhibitors of fibrin formation and promoters of 35 fibrinolysis such as t-PA, urokinase, Plasmin, Streptokinase, rt-Plasminogen Activator and rStaphylokinase; antiangiogenic factors such as

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medroxyprogesteron, pentosan polysulphate, suramin, taxol, thalidomide, angiostatin, interferon-alpha, metalloproteinase inhibitors, platelet factor 4, somatostatin, thrombospondin; circulatory drugs such as propranolol; metabolic potentiators such as glutathione; antituberculars such as p-aminosalicylic acid, isoniazid, capreomycin sulfate, cyclosexine, ethambutol, ethionamide, pyrazinamide, rifampin or streptomycin sulphate; antivirals such as acyclovir, amantadine, azidothymidine, ribavirin or vidarabine; blood vessel dilating agents such as diltiazem, nifedipine, verapamil, erythritol tetranitrate, isosorbide dinitrate, nitroglycerin or pentaerythritol tetranitrate; antibiotics such as dapsone, chloramphenicol, neomycin, cefaclor, cefadroxil, cephalexin, cephradine, erythromycin, clindamycin, lincomycin, amoxicillin, ampicillin, bacampicillin, carbenicillin, dicloxacillin, cyclacillin, picloxacillin, hetacillin, methicillin, nafcillin, penicillin, polymyxin or tetracycline; antiinflammatories such as diflunisal, ibuprofen, indomethacin, meclufenamate, mefenamic acid, naproxen, phenylbutazone, piroxicam, tolmetin, aspirin or salicylates; antiprotozoans such as chloroquine, metronidazole, quinine or meglumine antimonate; antirheumatics such as penicillamine; narcotics such as paregoric; opiates such as codeine, morphine or opium; cardiac glycosides such as deslaneside, digitoxin, digoxin, digitalin or digitalis; neuromuscular blockers such as atracurium mesylate, gallamine triethiodide, hexafluorenum bromide, metocurine iodide, pancuronium bromide, succinylcholine chloride, tubocurarine chloride or vecuronium bromide; sedatives such as amobarbital, amobarbital sodium, aprobarbital, butabarbital sodium, chloral hydrate, ethchlorvynol, ethinamate, flurazepam hydrochloride, glutethimide, methotrimeprazine hydrochloride, methypylon, midazolam hydrochloride,

paraldehyde, pentobarbital, secobarbital sodium, talbutal, temazepam or triazolam; local anaesthetics such as bupivacaine, chloroprocaine, etidocaine, lidocaine, mepivacaine, procaine or tetracaine; general
5 anaesthetics such as droperidol, etomidate, fentanyl citrate with droperidol, ketamine hydrochloride, methohexital sodium or thiopental and pharmaceutically acceptable salts (e.g. acid addition salts such as the hydrochloride or hydrobromide or base salts such as
10 sodium, calcium or magnesium salts) or derivatives (e.g. acetates) thereof. Other examples of therapeutics include genetic material such as nucleic acids, RNA, and DNA of natural or synthetic origin, including recombinant RNA and DNA. DNA encoding certain proteins
15 may be used in the treatment of many different types of diseases. For example, tumor necrosis factor or interleukin-2 genes may be provided to treat advanced cancers; thymidine kinase genes may be provided to treat ovarian cancer or brain tumors; interleukin-2
20 genes may be provided to treat neuroblastoma, malignant melanoma or kidney cancer; and interleukin-4 genes may be provided to treat cancer.

Lipophilic derivatives of drugs linked to the microbubble membrane through hydrophobic interactions
25 may exhibit therapeutic effects as part of the microbubble or after release from the microbubble, e.g. by use of ultrasound. If the drug does not possess the desired physical properties, a lipophilic group may be introduced for anchoring the drug to the membrane.
30 Preferably the lipophilic group should be introduced in a way that does not influence the *in vivo* potency of the molecule, or the lipophilic group may be cleaved releasing the active drug. Lipophilic groups may be introduced by various chemical means depending on
35 functional groups available in the drug molecule. Covalent coupling may be effected using functional groups in the drug molecule capable of reacting with

appropriately functionalised lipophilic compounds. Examples of lipophilic moieties include branched and unbranched alkyl chains, cyclic compounds, aromatic residues and fused aromatic and non-aromatic cyclic systems. In some instances the lipophilic moiety will consist of a suitably functionalised steroid, such as cholesterol or a related compound. Examples of functional groups particularly suitable for derivatisation include nucleophilic groups like amino, hydroxy and sulfhydryl groups. Suitable processes for lipophilic derivatisation of any drug containing a sulfhydryl group, such as captopril, may include direct alkylation, e.g. reaction with an alkyl halide under basic conditions and thiol ester formation by reaction with an activated carboxylic acid. Representative examples of derivatisation of any drug having carboxylic functions, for example atenolol or chlorambucil, include amide and ester formation by coupling respectively with amines and alcohols possessing appropriate physical properties. A preferred embodiment comprises attachment of cholesterol to a therapeutic compound by forming a degradable ester bond.

A preferred application of the present invention relates to *angiogenesis*, which is the formation of new blood vessels by branching from existing vessels. The primary stimulus for this process may be inadequate supply of nutrients and oxygen (hypoxia) to cells in a tissue. The cells may respond by secreting angiogenetic factors, of which there are many; one example is *vascular endothelial growth factor*. These factors initiate the secretion of proteolytic enzymes which break down the proteins of the basement membrane, as well as inhibitors which limit the action of these potentially harmful enzymes. The combined effect of loss of attachment and signals from the receptors for angiogenetic factors is to cause the endothelial cells to move, multiply, and rearrange themselves, and finally

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to synthesise a basement membrane around the new vessels.

5 Tumors must initiate angiogenesis when they reach millimeter size in order to keep up their rate of growth. As angiogenesis is accompanied by characteristic changes in the endothelial cells and their environment, this process is a promising target for therapeutic intervention. The transformations accompanying angiogenesis are also very promising for
10 diagnosis, a preferred example being malignant disease, but the concept also shows great promise in inflammation and a variety of inflammation-related diseases. These factors are also involved in re-vascularisation of infarcted parts of the myocardium, which occurs if a
15 stenosis is released within a short time.

A number of known receptors/targets associated with angiogenesis are given in subsequent tables. Using the targeting principles described in the present disclosure, angiogenesis may be detected by the majority
20 of the imaging modalities in use in medicine. Contrast-enhanced ultrasound may possess additional advantages, the contrast medium being microspheres which are restricted to the interior of blood vessels. Even if the target antigens are found on many cell types, the
25 microspheres will attach exclusively to endothelial cells.

So-called prodrugs may also be used in agents according to the invention. Thus drugs may be derivatised to alter their physicochemical properties
30 and to adapt them for inclusion into the reporter; such derivatised drugs may be regarded as prodrugs and are usually inactive until cleavage of the derivatising group regenerates the active form of the drug.

By targeting gas-filled microbubbles containing a
35 prodrug-activating enzyme to areas of pathology, one may image targeting the enzyme, making it possible to visualise when the microbubbles are targeted properly to

the area of pathology and at the same time have disappeared from non-target areas. In this way one can determine the optimal time for injection of prodrug into individual patients.

5 Another alternative is to incorporate the prodrug, prodrug-activating enzyme and vector in the same microbubbles in a system where the prodrug will only be activated after some external stimulus. Such a stimulus may, for example, be a tumour-specific protease as
10 described above, or bursting of the microbubbles by external ultrasound after the desired targeting has been achieved.

 Therapeutics may easily be delivered in accordance with the invention to diseased or necrotic areas, for
15 example in the heart, general vasculature, and to the liver, spleen, kidneys and other regions such as the lymph system, body cavities or gastrointestinal system.

 Products according to the present invention may be used for targeted therapeutic delivery either *in vivo* or
20 *in vitro*. In the latter context the products may be useful in *in vitro* systems such as kits for diagnosis of different diseases or characterisation of different components in blood or tissue samples. Similar techniques to those used to attach certain blood
25 components or cells to polymer particles (e.g. monodisperse magnetic particles) *in vitro* to separate them from a sample may be used in the present invention, using the low density of the reporter units in agents of the present invention to effect separation of the gas-
30 containing material by flotation and repeated washing.

 Coupling of a reporter unit to a desired vector (and/or therapeutic drug) may be achieved by covalent or non-covalent means, usually involving interaction with one or more functional groups located on the reporter
35 and/or vector and/or any intervening linker group/spacer element. Examples of chemically reactive functional groups which may be employed for this purpose include

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amino, hydroxyl, sulfhydryl, carboxyl, and carbonyl groups, as well as carbohydrate groups, vicinal diols, thioethers, 2-aminoalcohols, 2-aminothiols, guanidinyll, imidazolyl and phenolic groups.

5 Covalent coupling of reporter and vector may therefore be effected using linking agents containing reactive moieties capable of reaction with such functional groups. Examples of reactive moieties capable of reaction with sulfhydryl groups include α -
10 haloacetyl compounds of the type $X-CH_2CO-$ (where $X=Br, Cl$ or I), which show particular reactivity for sulfhydryl groups but which can also be used to modify imidazolyl, thioether, phenol and amino groups as described by Gurd, F.R.N. in *Methods Enzymol.* (1967) 11, 532. N-Maleimide
15 derivatives are also considered selective towards sulfhydryl groups, but may additionally be useful in coupling to amino groups under certain conditions. N-maleimides may be incorporated into linking systems for reporter-vector conjugation as described by Kitagawa, T.
20 et al. in *Chem. Pharm. Bull.* (1981) 29, 1130 or used as polymer crosslinkers for bubble stabilisation as described by Kovacic, P. et al. in *J. Am. Chem. Soc.* (1959) 81, 1887. Reagents such as 2-iminothiolane, e.g. as described by Traut, R. et al. in *Biochemistry* (1973)
25 12, 3266, which introduce a thiol group through conversion of an amino group, may be considered as sulfhydryl reagents if linking occurs through the formation of disulphide bridges. Thus reagents which introduce reactive disulphide bonds into either the
30 reporter or the vector may be useful, since linking may be brought about by disulphide exchange between the vector and reporter; examples of such reagents include Ellman's reagent (DTNB), 4,4'-dithiodipyridine, methyl-3-nitro-2-pyridyl disulphide and methyl-2-pyridyl
35 disulphide (described by Kimura, T. et al. in *Analyt. Biochem.* (1982) 122, 271).

Examples of reactive moieties capable of reaction

with amino groups include alkylating and acylating agents. Representative alkylating agents include:

- i) α -haloacetyl compounds, which show specificity towards amino groups in the absence of reactive thiol groups and are of the type $X-CH_2CO-$ (where $X=Cl, Br$ or I), e.g. as described by Wong, Y-H.H. in *Biochemistry* (1979) **24**, 5337;
- ii) N-maleimide derivatives, which may react with amino groups either through a Michael type reaction or through acylation by addition to the ring carbonyl group as described by Smyth, D.G. et al. in *J. Am. Chem. Soc.* (1960) **82**, 4600 and *Biochem. J.* (1964) **91**, 589;
- iii) aryl halides such as reactive nitrohaloaromatic compounds;
- iv) alkyl halides as described by McKenzie, J.A. et al. in *J. Protein Chem.* (1988) **7**, 581;
- v) aldehydes and ketones capable of Schiff's base formation with amino groups, the adducts formed usually being stabilised through reduction to give a stable amine;
- vi) epoxide derivatives such as epichlorohydrin and bisoxiranes, which may react with amino, sulfhydryl or phenolic hydroxyl groups;
- vii) chlorine-containing derivatives of s-triazines, which are very reactive towards nucleophiles such as amino, sulfhydryl and hydroxy groups;
- viii) aziridines based on s-triazine compounds detailed above, e.g. as described by Ross, W.C.J. in *Adv. Cancer Res.* (1954) **2**, 1, which react with nucleophiles such as amino groups by ring opening;
- ix) squaric acid diethyl esters as described by Tietze, L.F. in *Chem. Ber.* (1991) **124**, 1215; and
- x) α -haloalkyl ethers, which are more reactive alkylating agents than normal alkyl halides because of the activation caused by the ether oxygen atom, e.g. as described by Benneche, T. et al. in *Eur. J. Med. Chem.* (1993) **28**, 463.

Representative amino-reactive acylating agents include:

- i) isocyanates and isothiocyanates, particularly aromatic derivatives, which form stable urea and thiourea derivatives respectively and have been used for protein crosslinking as described by Schick, A.F. et al. in *J. Biol. Chem.* (1961) **236**, 2477;
- ii) sulfonyl chlorides, which have been described by Herzig, D.J. et al. in *Biopolymers* (1964) **2**, 349 and which may be useful for the introduction of a fluorescent reporter group into the linker;
- iii) Acid halides;
- iv) Active esters such as nitrophenylesters or N-hydroxysuccinimidyl esters;
- v) acid anhydrides such as mixed, symmetrical or N-carboxyanhydrides;
- vi) other useful reagents for amide bond formation as described by Bodansky, M. et al. in *'Principles of Peptide Synthesis'* (1984) Springer-Verlag;
- vii) acylazides, e.g. wherein the azide group is generated from a preformed hydrazide derivative using sodium nitrite, e.g. as described by Wetz, K. et al. in *Anal. Biochem.* (1974) **58**, 347;
- viii) azlactones attached to polymers such as bis-acrylamide, e.g. as described by Rasmussen, J.K. in *Reactive Polymers* (1991) **16**, 199; and
- ix) Imidoesters, which form stable amidines on reaction with amino groups, e.g. as described by Hunter, M.J. and Ludwig, M.L. in *J. Am. Chem. Soc.* (1962) **84**, 3491.

Carbonyl groups such as aldehyde functions may be reacted with weak protein bases at a pH such that nucleophilic protein side-chain functions are protonated. Weak bases include 1,2-aminothiols such as those found in N-terminal cysteine residues, which selectively form stable 5-membered thiazolidine rings with aldehyde groups, e.g. as described by Ratner, S. et

al. in *J. Am. Chem. Soc.* (1937) 59, 200. Other weak bases such as phenyl hydrazones may be used, e.g. as described by Heitzman, H. et al. in *Proc. Natl. Acad. Sci. USA* (1974) 71, 3537.

5 Aldehydes and ketones may also be reacted with amines to form Schiff's bases, which may advantageously be stabilised through reductive amination. Alkoxylamino moieties readily react with ketones and aldehydes to produce stable alkoxamines, e.g. as described by Webb, R. et al. in *Bioconjugate Chem.* (1990) 1, 96.

10 Examples of reactive moieties capable of reaction with carboxyl groups include diazo compounds such as diazoacetate esters and diazoacetamides, which react with high specificity to generate ester groups, e.g. as described by Herriot R.M. in *Adv. Protein Chem.* (1947) 3, 169. Carboxylic acid modifying reagents such as carbodiimides, which react through O-acylurea formation followed by amide bond formation, may also usefully be employed; linking may be facilitated through addition of an amine or may result in direct vector-receptor coupling. Useful water soluble carbodiimides include 1-cyclohexyl-3-(2-morpholinyl-4-ethyl)carbodiimide (CMC) and 1-ethyl-3-(3-dimethylaminopropyl)carbodiimide (EDC), e.g. as described by Zot, H.G. and Puett, D. in *J. Biol. Chem.* (1989) 264, 15552. Other useful carboxylic acid modifying reagents include isoxazolium derivatives such as Woodward's reagent K; chloroformates such as p-nitrophenylchloroformate; carbonyldiimidazoles such as 1,1'-carbonyldiimidazole; and N-carbalkoxydihydroquinolines such as N-(ethoxycarbonyl)-2-ethoxy-1,2-dihydroquinoline.

25 Other potentially useful reactive moieties include vicinal diones such as p-phenylenediglyoxal, which may be used to react with guanidinyll groups, e.g. as described by Wagner et al. in *Nucleic acid Res.* (1978) 5, 4065; and diazonium salts, which may undergo

electrophilic substitution reactions, e.g. as described by Ishizaka, K. and Ishizaka T. in *J. Immunol.* (1960) 85, 163. Bis-diazonium compounds are readily prepared by treatment of aryl diamines with sodium nitrite in acidic solutions. It will be appreciated that functional groups in the reporter and/or vector may if desired be converted to other functional groups prior to reaction, e.g. to confer additional reactivity or selectivity. Examples of methods useful for this purpose include conversion of amines to carboxylic acids using reagents such as dicarboxylic anhydrides; conversion of amines to thiols using reagents such as N-acetylhomocysteine thiolactone, S-acetylmercaptosuccinic anhydride, 2-iminothiolane or thiol-containing succinimidyl derivatives; conversion of thiols to carboxylic acids using reagents such as α -haloacetates; conversion of thiols to amines using reagents such as ethylenimine or 2-bromoethylamine; conversion of carboxylic acids to amines using reagents such as carbodiimides followed by diamines; and conversion of alcohols to thiols using reagents such as tosyl chloride followed by transesterification with thioacetate and hydrolysis to the thiol with sodium acetate.

Vector-reporter coupling may also be effected using enzymes as zero-length linking agents; thus, for example, transglutaminase, peroxidase and xanthine oxidase may be used to produce linked products. Reverse proteolysis may also be used for linking through amide bond formation.

Non-covalent vector-reporter coupling may, for example, be effected by electrostatic charge interactions e.g. between a polylysinyll-functionalised reporter and a polyglutamyl-functionalised vector, through chelation in the form of stable metal complexes or through high affinity binding interaction such as avidin/biotin binding. Polylysine, coated non-covalently to a negatively charged membrane surface may

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also increase non-specifically the affinity of a microbubble for a cell through charge interactions.

Alternatively, a vector may be coupled to a protein known to bind phospholipids. In many instances, a single molecule of phospholipid may attach to a protein such as a translocase, while other proteins may attach to surfaces consisting mainly of phospholipid head groups and so may be used to attach vectors to phospholipid microspheres; one example of such a protein is β 2-glycoprotein I (Chonn, A., Semple, S.C. and Cullis, P.R., *Journal of Biological Chemistry* (1995) **270**, 25845-25849). Phosphatidylserine-binding proteins have been described, e.g. by Igarashi, K. et al. in *Journal of Biological Chemistry* **270**(49), 29075-29078; a conjugate of a vector with such a phosphatidylserine-binding protein may therefore be used to attach the vector to phosphatidylserine-encapsulated microbubbles. When the amino acid sequence of a binding protein is known, the phospholipid-binding portion may be synthesised or isolated and used for conjugation with a vector, thus avoiding the biological activity which may be located elsewhere in the molecule.

It is also possible to obtain molecules that bind specifically to the surface (or in the "membrane") of microspheres by direct screening of molecular libraries for microsphere-binding molecules. For example, phage libraries displaying small peptides may be used for such selection. The selection may be made by simply mixing the microspheres and the phage display library and eluting the phages binding to the floating microspheres. If desired, the selection may be done under "physiological conditions" (e.g. in blood) to eliminate peptides which cross-react with blood components. An advantage of this type of selection procedure is that only binding molecules that do not destabilise the microspheres should be selected, since only binding molecules attached to intact floating microspheres will

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rise to the top. It may also be possible to introduce some kind of "stress" during the selection procedure (e.g. pressure) to ensure that destabilising binding moieties are not selected. Furthermore the selection
5 may be done under shear conditions, for example by first letting the phages react with the microspheres and then letting the microspheres pass through a surface coated with anti-phage antibodies under flow conditions. In this way it may be possible to select binders which may
10 resist shear conditions present *in vivo*. Binding moieties identified in this way may be coupled (by chemical conjugation or via peptide synthesis, or at the DNA-level for recombinant vectors) to a vector molecule, constituting a general tool for attaching any vector
15 molecule to the microspheres.

A vector which comprises or is coupled to a peptide, lipo-oligosaccharide or lipopeptide linker which contains a element capable of mediating membrane insertion may also be useful. One example is described
20 by Leenhouts, J.M. et al. in *Febs Letters* (1995) 370(3), 189-192. Non-bioactive molecules consisting of known membrane insertion anchor/signal groups may also be used as vectors for certain applications, an example being the H1 hydrophobic segment from the Na,K-ATPase α -
25 subunit described by Xie, Y. and Morimoto, T. in *J. Biol. Chem.* (1995) 270(20), 11985-11991. The anchor group may also be fatty acid(s) or cholesterol.

Coupling may also be effected using avidin or streptavidin, which have four high affinity binding
30 sites for biotin. Avidin may therefore be used to conjugate vector to reporter if both vector and reporter are biotinylated. Examples are described by Bayer, E.A. and Wilchek, M. in *Methods Biochem. Anal.* (1980) 26, 1. This method may also be extended to include linking of
35 reporter to reporter, a process which may encourage bubble association and consequent potentially increased echogenicity. Alternatively, avidin or streptavidin may

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be attached directly to the surface of reporter microparticles.

Non-covalent coupling may also utilise the bifunctional nature of bispecific immunoglobulins.

5 These molecules can specifically bind two antigens, thus linking them. For example, either bispecific IgG or chemically engineered bispecific F(ab)'₂ fragments may be used as linking agents. Heterobifunctional bispecific antibodies have also been reported for linking two
10 different antigens, e.g. as described by Bode, C. et al. in *J. Biol. Chem.* (1989) 264, 944 and by Staerz, U.D. et al. in *Proc. Natl. Acad. Sci. USA* (1986) 83, 1453. Similarly, any reporter and/or vector containing two or more antigenic determinants (e.g. as described by Chen,
15 Aa et al. in *Am. J. Pathol.* (1988) 130, 216) may be crosslinked by antibody molecules and lead to formation of multi-bubble cross-linked assemblies of potentially increased echogenicity.

Linking agents used in accordance with the
20 invention will in general bring about linking of vector to reporter or reporter to reporter with some degree of specificity, and may also be used to attach one or more therapeutically active agents.

25 In some instances it is considered advantageous to include a PEG component as a stabiliser in conjunction with a vector or vectors or directly to the reporter in the same molecule where the PEG does not serve as a spacer.

30 So-called zero-length linking agents, which induce direct covalent joining of two reactive chemical groups without introducing additional linking material (e.g. as in amide bond formation induced using carbodiimides or enzymatically) may, if desired, be used in accordance with the invention, as may agents such as biotin/avidin
35 systems which induce non-covalent reporter-vector linking and agents which induce hydrophobic or electrostatic interactions.

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Most commonly, however, the linking agent will comprise two or more reactive moieties, e.g. as described above, connected by a spacer element. The presence of such a spacer permits bifunctional linkers to react with specific functional groups within a molecule or between two different molecules, resulting in a bond between these two components and introducing extrinsic linker-derived material into the reporter-vector conjugate. The reactive moieties in a linking agent may be the same (homobifunctional agents) or different (heterobifunctional agents or, where several dissimilar reactive moieties are present, heteromultifunctional agents), providing a diversity of potential reagents that may bring about covalent bonding between any chemical species, either intramolecularly or intermolecularly.

The nature of extrinsic material introduced by the linking agent may have a critical bearing on the targeting ability and general stability of the ultimate product. Thus it may be desirable to introduce labile linkages, e.g. containing spacer arms which are biodegradable or chemically sensitive or which incorporate enzymatic cleavage sites. Alternatively the spacer may include polymeric components, e.g. to act as surfactants and enhance bubble stability. The spacer may also contain reactive moieties, e.g. as described above to enhance surface crosslinking, or it may contain a tracer element such as a fluorescent probe, spin label or radioactive material.

Contrast agents according to the present invention are therefore useful in all imaging modalities since contrast elements such as X-ray contrast agents, light imaging probes, spin labels or radioactive units may readily be incorporated in or attached to the reporter units.

Spacer elements may typically consist of aliphatic chains which effectively separate the reactive moieties

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of the linker by distances of between 5 and 30 Å. They may also comprise macromolecular structures such as PEGs, which have been given much attention in biotechnical and biomedical applications (see e.g. Milton Harris, J. (ed) "Poly(ethylene glycol) chemistry, biotechnical and biomedical applications" Plenum Press, New York, 1992). PEGs are soluble in most solvents, including water, and are highly hydrated in aqueous environments, with two or three water molecules bound to each ethylene glycol segment; this has the effect of preventing adsorption either of other polymers or of proteins onto PEG-modified surfaces. PEGs are known to be nontoxic and not to harm active proteins or cells, whilst covalently linked PEGs are known to be non-immunogenic and non-antigenic. Furthermore, PEGs may readily be modified and bound to other molecules with only little effect on their chemistry. Their advantageous solubility and biological properties are apparent from the many possible uses of PEGs and copolymers thereof, including block copolymers such as PEG-polyurethanes and PEG-polypropylenes.

Appropriate molecular weights for PEG spacers used in accordance with the invention may, for example, be between 120 Daltons and 20 kDaltons.

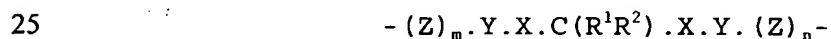
The major mechanism for uptake of particles by the cells of the reticuloendothelial system (RES) is opsonisation by plasma proteins in blood; these mark foreign particles which are then taken up by the RES. The biological properties of PEG spacer elements used in accordance with the invention may serve to increase contrast agent circulation time in a similar manner to that observed for PEGylated liposomes (see e.g. Klibanov, A.L. et al. in *FEBS Letters* (1990) 268, 235-237 and Blume, G. and Cevc, G. in *Biochim. Biophys. Acta* (1990) 1029, 91-97). Increased coupling efficiency to areas of interest may also be achieved using antibodies bound to the termini of PEG spacers (see e.g. Maruyama,

K. et al. in *Biochim. Biophys. Acta* (1995) 1234, 74-80
and Hansen, C.B. et al. in *Biochim. Biophys. Acta* (1995)
1239, 133-144).

In some instances it is considered advantageous to
5 include a PEG component as a stabiliser in conjunction
with a vector or vectors or directly to the reporter in
the same molecule where the PEG does not serve as a
spacer.

Other representative spacer elements include
10 structural-type polysaccharides such as polygalacturonic
acid, glycosaminoglycans, heparinoids, cellulose and
marine polysaccharides such as alginates, chitosans and
carrageenans; storage-type polysaccharides such as
starch, glycogen, dextran and aminodextrans; polyamino
15 acids and methyl and ethyl esters thereof, as in homo-
and co-polymers of lysine, glutamic acid and aspartic
acid; and polypeptides, oligosaccharides and
oligonucleotides, which may or may not contain enzyme
cleavage sites.

20 In general, spacer elements may contain cleavable
groups such as vicinal glycol, azo, sulfone, ester,
thioester or disulphide groups. Spacers containing
biodegradable methylene diester or diamide groups of
formula



[where X and Z are selected from -O-, -S-, and -NR-
(where R is hydrogen or an organic group); each Y is a
carbonyl, thiocarbonyl, sulphonyl, phosphoryl or similar
acid-forming group; m and n are each zero or 1; and R¹
30 and R² are each hydrogen, an organic group or a group
-X.Y.(Z)_m-, or together form a divalent organic group]
may also be useful; as discussed in, for example, WO-A-
9217436 such groups are readily biodegraded in the
presence of esterases, e.g. *in vivo*, but are stable in
35 the absence of such enzymes. They may therefore
advantageously be linked to therapeutic agents to permit
slow release thereof.

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Poly[N-(2-hydroxyethyl)methacrylamides] are potentially useful spacer materials by virtue of their low degree of interaction with cells and tissues (see e.g. Volfová, I., Ríhová, B. and V.R. and Vetvicka, P. in *J. Bioact. Comp. Polymers* (1992) 7, 175-190). Work on a similar polymer consisting mainly of the closely related 2-hydroxypropyl derivative showed that it was endocytosed by the mononuclear phagocyte system only to a rather low extent (see Goddard, P., Williamson, I., Bron, J., Hutchkinson, L.E., Nicholls, J. and Petrak, K. in *J. Bioact. Compat. Polym.* (1991) 6, 4-24.).

Other potentially useful polymeric spacer materials include:

- i) copolymers of methyl methacrylate with methacrylic acid; these may be erodible (see Lee, P.I. in *Pharm. Res.* (1993) 10, 980) and the carboxylate substituents may cause a higher degree of swelling than with neutral polymers;
- ii) block copolymers of polymethacrylates with biodegradable polyesters (see e.g. San Roman, J. and Guillen-Garcia, P. in *Biomaterials* (1991) 12, 236-241);
- iii) cyanoacrylates, i.e. polymers of esters of 2-cyanoacrylic acid - these are biodegradable and have been used in the form of nanoparticles for selective drug delivery (see Forestier, F., Gerrier, P., Chaumard, C., Quero, A.M., Couvreur, P. and Labarre, C. in *J. Antimicrob. Chemoter.* (1992) 30, 173-179);
- iv) polyvinyl alcohols, which are water-soluble and generally regarded as biocompatible (see e.g. Langer, R. in *J. Control. Release* (1991) 16, 53-60);
- v) copolymers of vinyl methyl ether with maleic anhydride, which have been stated to be bioerodible (see Finne, U., Hannus, M. and Urtti, A. in *Int. J. Pharm.* (1992) 78, 237-241);
- vi) polyvinylpyrrolidones, e.g. with molecular weight less than about 25,000, which are rapidly filtered by the kidneys (see Hespe, W., Meier, A. M. and

- Blankwater, Y. M. in *Arzeim.-Forsch./Drug Res.* (1977) 27, 1158-1162);
- vii) polymers and copolymers of short-chain aliphatic hydroxyacids such as glycolic, lactic, butyric, valeric and caproic acids (see e.g. Carli, F. in *Chim. Ind. (Milan)* (1993) 75, 494-9), including copolymers which incorporate aromatic hydroxyacids in order to increase their degradation rate (see Imasaki, K., Yoshida, M., Fukuzaki, H., Asano, M., Kumakura, M., Mashimo, T., Yamanaka, H. and Nagai, T. in *Int. J. Pharm.* (1992) 81, 31-38);
- viii) polyesters consisting of alternating units of ethylene glycol and terephthalic acid, e.g. Dacron^R, which are non-degradable but highly biocompatible;
- ix) block copolymers comprising biodegradable segments of aliphatic hydroxyacid polymers (see e.g. Younes, H., Nataf, P.R., Cohn, D., Appelbaum, Y.J., Pizov, G. and Uretzky, G. in *Biomater. Artif. Cells Artif. Organs* (1988) 16, 705-719), for instance in conjunction with polyurethanes (see Kobayashi, H., Hyon, S.H. and Ikada, Y. in "Water-curable and biodegradable prepolymers" - *J. Biomed. Mater. Res.* (1991) 25, 1481-1494);
- x) polyurethanes, which are known to be well-tolerated in implants, and which may be combined with flexible "soft" segments, e.g. comprising poly(tetramethylene glycol), poly(propylene glycol) or poly(ethylene glycol) and aromatic "hard" segments, e.g. comprising 4,4'-methylenebis(phenylene isocyanate) (see e.g. Ratner, B.D., Johnston, A.B. and Lenk, T.J. in *J. Biomed. Mater. Res: Applied Biomaterials* (1987) 21, 59-90; Sa Da Costa, V. et al. in *J. Coll. Interface Sci.* (1981) 80, 445-452 and Affrossman, S. et al. in *Clinical Materials* (1991) 8, 25-31);
- xi) poly(1,4-dioxan-2-ones), which may be regarded as biodegradable esters in view of their hydrolysable ester linkages (see e.g. Song, C. X., Cui, X. M. and Schindler, A. in *Med. Biol. Eng. Comput.* (1993) 31,

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S147-150), and which may include glycolide units to improve their absorbability (see Bezwada, R.S., Shalaby, S.W. and Newman, H.D.J. in *Agricultural and synthetic polymers: Biodegradability and utilization (1990)* (ed Glass, J.E. and Swift, G.), 167-174 - ACS symposium Series, #433, Washington D.C., U.S.A. - American Chemical Society);

xii) polyanhydrides such as copolymers of sebacic acid (octanedioic acid) with bis(4-carboxy-phenoxy)propane, which have been shown in rabbit studies (see Brem, H., Kader, A., Epstein, J.I., Tamargo, R.J., Domb, A., Langer, R. and Leong, K.W. in *Sel. Cancer Ther.* (1989) 5, 55-65) and rat studies (see Tamargo, R.J., Epstein, J.I., Reinhard, C.S., Chasin, M. and Brem, H. in *J. Biomed. Mater. Res.* (1989) 23, 253-266) to be useful for controlled release of drugs in the brain without evident toxic effects;

xiii) biodegradable polymers containing ortho-ester groups, which have been employed for controlled release *in vivo* (see Maa, Y.F. and Heller, J. in *J. Control. Release* (1990) 14, 21-28); and

xiv) polyphosphazenes, which are inorganic polymers consisting of alternate phosphorus and nitrogen atoms (see Crommen, J.H., Vandorpe, J. and Schacht, E.H. in *J. Control. Release* (1993) 24, 167-180).

The following tables list linking agents and agents for protein modification which may be useful in preparing targetable agents in accordance with the invention.

Heterobifunctional linking agents

Linking agent	Reactivity 1	Reactivity 2	Comments
ABH	carbohydrate	photoreactive	
ANB-NOS	-NH ₂	photoreactive	

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	APDP (1)	-SH	photoreactive	iodinable disulphide linker
	APG	-NH ₂	photoreactive	reacts selectively with Arg at pH 7-8
	ASIB (1)	-SH	photoreactive	iodinable
	ASBA (1)	-COOH	photoreactive	iodinable
5	EDC	-NH ₂	-COOH	zero-length linker
	GMBS	-NH ₂	-SH	
	sulfo-GMBS	-NH ₂	-SH	water-soluble
	HSAB	-NH ₂	photoreactive	
	sulfo-HSAB	-NH ₂	photoreactive	water-soluble
10	MBS	-NH ₂	-SH	
	sulfo-MBS	-NH ₂	-SH	water-soluble
	M ₂ C ₂ H	carbohydrate	-SH	
	MPBH	carbohydrate	-SH	
	NHS-ASA (1)	-NH ₂	photoreactive	iodinable
15	sulfo-NHS- ASA (1)	-NH ₂	photoreactive	water-soluble, iodinable
	sulfo-NHS-LC- ASA (1)	-NH ₂	photoreactive	water-soluble, iodinable
	PDPH	carbohydrate	-SH	disulphide linker
20	PNP-DTP	-NH ₂	photoreactive	
	SADP	-NH ₂	photoreactive	disulphide linker
	sulfo-SADP	-NH ₂	photoreactive	water-soluble disulphide linker

	SAED	-NH ₂	photoreactive	disulphide linker
	SAND	-NH ₂	photoreactive	water-soluble disulphide linker
	SANPAH	-NH ₂	photoreactive	
	sulfo-SANPAH	-NH ₂	photoreactive	water-soluble
5	SASD(1)	-NH ₂	photoreactive	water-soluble iodineable disulphide linker
	SIAB	-NH ₂	-SH	
	sulfo-SIAB	-NH ₂	-SH	water-soluble
	SMCC	-NH ₂	-SH	
	sulfo-SMCC	-NH ₂	-SH	water-soluble
10	SMPB	-NH ₂	-SH	
	sulfo-SMPB	-NH ₂	-SH	water-soluble
	SMPT	-NH ₂	-SH	
	sulfo-LC-SMPT	-NH ₂	-SH	water-soluble
	SPDP	-NH ₂	-SH	
15	sulfo-SPDP	-NH ₂	-SH	water-soluble
	sulfo-LC-SPDP	-NH ₂	-SH	water-soluble
	sulfo-SAMCA(2)	-NH ₂	photoreactive	
	sulfo-SAPB	-NH ₂	photoreactive	water-soluble

20 Notes: (1)=iodineable; (2)=fluorescent

Homobifunctional linking agents

	Linking agent	Reactivity	Comments
25	BS	-NH ₂	
	BMH	-SH	
	BASED(1)	photoreactive	iodineable disulphide linker

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	BSCOES	-NH ₂	
	sulfo-BSCOES	-NH ₂	water-soluble
	DFDNB	-NH ₂	
	DMA	-NH ₂	
5	DMP	-NH ₂	
	DMS	-NH ₂	
	DPDPB	-SH	disulphide linker
	DSG	-NH ₂	
	DSP	-NH ₂	disulphide linker
10	DSS	-NH ₂	
	DST	-NH ₂	
	sulfo-DST	-NH ₂	water-soluble
	DTBP	-NH ₂	disulphide linker
	DTSSP	-NH ₂	disulphide linker
15	EGS	-NH ₂	
	sulfo-EGS	-NH ₂	water-soluble
	SPBP	-NH ₂	

Biotinylation agents

20

25

Agent	Reactivity	Comments
biotin-BMCC	-SH	
biotin-DPPE*		preparation of biotinylated liposomes
biotin-LC-DPPE*		preparation of biotinylated liposomes
biotin-HPDP	-SH	disulphide linker
biotin-hydrazide	carbohydrate	
biotin-LC-hydrazide	carbohydrate	
iodoacetyl-LC-biotin	-NH ₂	
NHS-iminobiotin	-NH ₂	reduced affinity for avidin

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NHS-SS-biotin	-NH ₂	disulphide linker
photoactivatable biotin	nucleic acids	
sulfo-NHS-biotin	-NH ₂	water-soluble
sulfo-NHS-LC-biotin	-NH ₂	

5

Notes: DPPE=dipalmitoylphosphatidylethanolamine; LC=long chain

Agents for protein modification

10

Agent	Reactivity	Function
Ellman's reagent	-SH	quantifies/detects/protects
DTT	-S.S-	reduction
2-mercaptoethanol	-S.S-	reduction
2-mercaptylamine	-S.S-	reduction
15 Traut's reagent	-NH ₂	introduces -SH
SATA	-NH ₂	introduces protected -SH
AMCA-NHS	-NH ₂	fluorescent labelling
AMCA-hydrazide	carbohydrate	fluorescent labelling
AMCA-HPDP	-S.S-	fluorescent labelling
20 SBF-chloride	-S.S-	fluorescent detection of -SH
N-ethylmaleimide	-S.S-	blocks -SH
NHS-acetate	-NH ₂	blocks and acetylates -NH ₂
citraconic anhydride	-NH ₂	reversibly blocks and introduces negative charges
DTPA	-NH ₂	introduces chelator
25 BNPS-skatole	tryptophan	cleaves tryptophan residue
Bolton-Hunter	-NH ₂	introduces iodine group

30

Other potentially useful protein modifications include partial or complete deglycosylation by neuraminidase, endoglycosidases or periodate, since deglycosylation often results in less uptake by liver,

spleen, macrophages etc., whereas neo-glycosylation of proteins often results in increased uptake by the liver and macrophages); preparation of truncated forms by proteolytic cleavage, leading to reduced size and shorter half life in circulation; and cationisation, e.g. as described by Kumagi et al. in *J. Biol. Chem.* (1987) 262, 15214-15219; Triguero et al. in *Proc. Natl. Acad. Sci. USA* (1989) 86, 4761-4765; Pardridge et al. in *J. Pharmacol. Exp. Therap.* (1989) 251, 821-826 and Pardridge and Boado, *Febs Lett.* (1991) 288, 30-32.

Vectors which may be usefully employed in targetable agents according to the invention include the following:

- i) Antibodies, which can be used as vectors for a very wide range of targets, and which have advantageous properties such as very high specificity, high affinity (if desired), the possibility of modifying affinity according to need etc. Whether or not antibodies will be bioactive will depend on the specific vector/target combination. Both conventional and genetically engineered antibodies may be employed, the latter permitting engineering of antibodies to particular needs, e.g. as regards affinity and specificity. The use of human antibodies may be preferred to avoid possible immune reactions against the vector molecule. A further useful class of antibodies comprises so-called bi- and multi-specific antibodies, i.e. antibodies having specificity for two or more different antigens in one antibody molecule. Such antibodies may, for example, be useful in promoting formation of bubble clusters and may also be used for various therapeutic purposes, e.g. for carrying toxic moieties to the target. Various aspects of bispecific antibodies are described by McGuinness, B.T. et al. in *Nat. Biotechnol.* (1996) 14, 1149-1154; by George, A.J. et al. in *J. Immunol.* (1994) 152, 1802-1811; by Bonardi et al. in

Cancer Res. (1993) 53, 3015-3021; and by French, R.R. et al. in *Cancer Res.* (1991) 51, 2353-2361.

ii) Cell adhesion molecules, their receptors,
5 cytokines, growth factors, peptide hormones and pieces thereof. Such vectors rely on normal biological protein-protein interactions with target molecule receptors, and so in many cases will generate a biological response on binding with the targets and thus
10 be bioactive; this may be a relatively insignificant concern with vectors which target proteoglycans.

iii) Non-peptide agonists/antagonists or non-bioactive binders of receptors for cell adhesion molecules,
15 cytokines, growth factors and peptide hormones. This category may include non-bioactive vectors which will be neither agonists nor antagonist but which may nonetheless exhibit valuable targeting ability.

20 iv) Oligonucleotides and modified oligonucleotides which bind DNA or RNA through Watson-Crick or other types of base-pairing. DNA is usually only present in extracellular space as a consequence of cell damage, so that such oligonucleotides, which will usually be non-
25 bioactive, may be useful in, for example, targeting of necrotic regions, which are associated with many different pathological conditions. Oligonucleotides may also be designed to bind to specific DNA- or RNA-binding proteins, for example transcription factors which are
30 very often highly overexpressed or activated in tumour cells or in activated immune or endothelial cells. Combinatorial libraries may be used to select oligonucleotides which bind specifically to any possible target molecules and which therefore may be employed as
35 vectors for targeting.

v) DNA-binding drugs may behave similarly to

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oligonuclotides, but may exhibit biological acitvity and/or toxic effects if taken up by cells.

5 vi) Protease substrates/inhibitors. Proteases are involved in many pathological conditions. Many substrates/inhibitors are non-peptidic but, at least in the case of inhibitors, are often bioactive.

10 vii) Vector molecules may be generated from combinatorial libraries without necessarily knowing the exact molecular target, by functionally selecting (*in vitro*, *ex vivo* or *in vivo*) for molecules binding to the region/structure to be imaged.

15 viii) Various small molecules, including bioactive compounds known to bind to biological receptors of various kinds. Such vectors or their targets may be used for generate non-bioactive compounds binding to the same targets.

20 ix) Proteins or peptides which bind to glucosamio glycan side chains e.g. heparan sulphate, including glucosoaminoglycan-binding portions of larger molecules, as binding to glucosoaminoglycans does not
25 result in a biological response. Proteoglycans are not found on red blood cells, which eliminates undesirable adsorption to these cells.

Other peptide vectors and lipopeptides thereof of
30 particular interest for targeted ultrasound imaging are listed below: Atherosclerotic plaque binding peptides such as YRALVDTLK, YAKFRETLEDTRDRMY and RALVDTEFKVKQEAGAK; Thrombus binding peptides such as NDGDFEEIPEEYLQ and GPRG, Platelet binding peptides such
35 as PLYKKIIKKLLES; and cholecystokinin, α -melanocyte-stimulating hormone, heat stable enterotoxin 1, vasoactive intestinal peptide, synthetic alpha-M2

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peptide from the third heavy chain complementarity-determining region and analogues thereof for tumour targeting.

- 5 The following tables identify various vectors which may be targeted to particular types of targets and indicated areas of use for targetable diagnostic and/or therapeutic agents according to the invention which contain such vectors.

10 Protein and peptide vectors - antibodies

	Vector type	Target	Comments/areas of use	Ref
	antibodies (general)	CD34	vascular diseases in general, normal vessel wall (e.g myocardium), activated endothelium, immune cells	1
15	"	ICAM-1	"	1
	"	ICAM-2	"	1
	"	ICAM-3	"	1
	"	E-selectin	"	1
	"	P-selectin	"	1
20	"	PECAM	"	1
	"	Integrins, e.g. VLA-1, VLA-2, VLA-3, VLA-4, VLA-5, VLA-6, $\beta_1\alpha_7$, $\beta_1\alpha_8$, $\beta_1\alpha_v$, LFA-1, Mac-1, CD41a, etc.	"	2
	"	GlyCAM	Vessel wall in lymph nodes (quite specific for lymph nodes)	3
	"	MadCam 1	"	3

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5	"	fibrin	Thrombi	4
	"	Tissue Factor	Activated endothelium, tumours	5
	"	Myosin	Necrosis, myocardial infaction	6
	"	CEA (carcino- embryonal antigen)	Tumours	7
	"	Mucins	Tumours	8
	"	Multiple drug resistance protein	Tumours	9
	"	Prostate specific antigen	Prostate cancer	
	"	Cathepsin B	Tumours (proteases of various kinds are often more or less specifically overexpressed in a variety of tumours - Cathepsin B is such a protease)	10
	"	Transferrin receptor	Tumors, vessel wall	11
	MoAb 9.2.27		Tumours Antigen upregulated on cell growth	12
10		VAP-1	Adhesion molecule	13

		Band 3 protein	Upregulated during phagocytic activity	
5	antibodies	CD34(sialomucin)	endothelial cells	
	antibodies	CD31(PECAM-1)	endothelial cells	
10	antibodies	intermediate filaments necrotic cells/tissue		
15	antibodies	CD44	tumour cells	a
	antibodies	β2-microglobulin	general	b
	antibodies	MHC class 1	general	b
20	antibodies	integrin αvβ3	tumours; angiogenesis	c

References

- 25 a) Heider, K. H., M. Sproll, S. Susani, E. Patzelt, P. Beaumier, E. Ostermann, H. Ahorn, and G. R. Adolf. 1996. "Characterization of a high-affinity monoclonal antibody specific for CD44v6 as candidate for immunotherapy of squamous cell carcinomas". *Cancer Immunology Immunotherapy* 43: 245-253.
- 30 b) I. Roitt, J. Brostoff, and D. Male. 1985. *Immunology*, London: Gower Medical Publishing, p. 4.7
- 35 c) Stromblad, S., and D. A. Cheresh. 1996. "Integrins, angiogenesis and vascular cell survival". *Chemistry & Biology* 3: 881-885.

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Protein and peptide vectors - cell adhesion molecules
etc.

	Vector type	Target	Comments/areas of use	Ref
5	L-selectin	CD34 MadCAM1 GlyCam 1	vascular diseases in general, normal vessel wall (e.g myocardium), activated endothelium, Lymph nodes	3
	Other selectins	carbohydrate ligands (sialyl Lewis x) heparan sulfate	vascular diseases in general, normal vessel wall (e.g myocardium), activated endothelium	14
	RGD-peptides	integrins	"	2
	PECAM	PECAM, and other	Endothelium, Cells in immune system	15
10	Integrins, e.g. VLA-1, VLA- 2, VLA-3, VLA-4, VLA-5, VLA-6, $\beta_1\alpha_7$, $\beta_1\alpha_8$, $\beta_1\alpha_v$, LFA-1, Mac-1, CD41a, etc.	Laminin, collagen, fibronectin, VCAM-1, thrombo- spondin, vitronectin etc.	Endothelium, Vessel wall etc.	16
15				
20	Integrin receptors, e.g. Laminin, collagen, fibronectin, VCAM-1, thrombospondin, vitronectin etc.	Integrins, e.g. VLA-1, VLA- 2, VLA-3, VLA-4, VLA-5, VLA-6, $\beta_1\alpha_7$, $\beta_1\alpha_8$, $\beta_1\alpha_v$, LFA-1, Mac-1, CD41a, etc.	Cells in immune system vessel wall etc.	17 18

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5	Nerve cell adhesion molecule (N-CAM)	proteoglycans N-CAM (homophilic)		19
	integrin $\alpha\beta 3$	CD31 (PECAM-1)	endothelial cells	
	RGD-peptides	integrins	angiogenesis	c

10 Vectors comprising cytokines/growth factors/peptide hormones and fragments thereof

	Vector type	Target	Comments/areas of use	Ref
15	Epidermal growth factor	EGF-receptor or related receptors	Tumours	20
	Nerve growth factor	NGF-receptor	Tumours	21
	Somatostatin	ST-receptor	Tumours	22
20	Endothelin	Endothelin-receptor	Vessel wall	
	Interleukin-1	IL-1-receptor	Inflammation, activated cells of different kinds	23
	Interleukin-2	IL-2-receptor	"	24
25	Chemokines (ca. 20 different cytokines partly sharing receptors)	Chemokine receptors, proteoglycans	Inflammation	25
	Tumour necrosis factor	TNF-receptors	Inflammation	
	Parathyroid hormone	PTH-receptors	Bone diseases Kidney diseases	

30

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	Bone Morphogenetic Protein	BMP-receptors	Bone Diseases	
	Calcitonin	CT-receptors	Bone diseases	
5	Colony stimulating factors (G-CSF, GM-CSF, M-CSF, IL-3)	Corresponding specific receptors, proteoglycans	Endothelium	26
10	Insulin like growth factor I	IGF-I receptor	Tumours, other growing tissues	
	Atrial Natriuretic Factor	ANF-receptors	Kidney, vessel wall	
15	Vasopressin	Vasopressin receptor	Kidney, vessel wall	
	VEGF	VEGF-receptor	Endothelium, regions of angiogenesis	
	Fibroblast growth factors	FGF-receptors, Proteoglycans	Endothelium Angiogenesis	27
20	Schwann cell growth factor	proteoglycans specific receptors		28

Miscellaneous protein and peptide vectors

25	Vector type	Target	Comments/areas of use	Ref
	Streptavidin	Kidney	Kidney diseases	29
	Bacterial fibronectin-binding proteins	Fibronectin	Vessel wall	30

	Fc-part of antibodies	Fc-receptors	Monocytes macrophages liver	31
	Transferrin	transferrin-receptor	Tumours vessel walls	11
5	Streptokinase/ tissue plasminogen activator	thrombi	thrombi	
	Plasminogen, plasmin	Fibrin	Thrombi, tumours	32
10	Mast cell proteinases	proteoglycans		33
	Elastase	proteoglycans		34
	Lipoprotein lipase	proteoglycans		35
15	Coagulation enzymes	proteoglycans		36
	Extracellular superoxide dismutase	proteoglycans		37
20	Heparin cofactor II	proteoglycans		38
	Retinal survival factor	proteoglycans specific receptors		39
25	Heparin-binding brain mitogen	proteoglycans specific receptors		40
	Apolipoprotein, e.g. apolipoprotein B	proteoglycans specific receptors (e.g., LDL receptor)		41

5	Apolipoprotein E	LDL receptor proteoglycans		42
	Adhesion- promoting proteins, e.g. Purpurin	proteoglycans		43
	Viral coat proteins, e.g. HIV, Herpes	proteoglycans		44
10	Microbial adhesins, e.g. "Antigen 85" complex of mycobacteria	fibronectin, collagen, fibrinogen, vitronectin, heparan sulfate		45
15	β -amyloid precursor	proteoglycans	β -amyloid accumulates in Alzheimer's disease	46
	Tenascin, e.g. tenascin C	heparan sulfate, integrins		47

- 20 Vectors comprising non-peptide agonists/antagonists or non-bioactive binders of receptors for cytokines/growth factors/peptide hormones/cell adhesion molecules

25	Vector type	Target	Comments/areas of use	Ref
			Several agonists/antagonists are known for such factors acting through G-protein coupled receptors	48 49
30	Endothelin antagonist	Endothelin receptor	Vessel wall	
	Desmopressin (vasopressin analogue)	Vasopressin receptor	Kidney Vessel wall	

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	Demoxytocin (oxytocin analogue)	Oxytocin Receptor	Reproductive organs, Mammary glands, Brain	
5	Angiotensin II receptor antagonists CV-11974, TCV-116	Angiotensin II receptors	Vessel wall brain adrenal gland	
10	non-peptide RGD- analogues	integrins	Cells in immune system vessel wall etc.	50

Vectors comprising anti-angiogenic factors

15	Vector type	Target	Comments/areas of use	Ref
	Angiostatin	EC of tumors	plasminogen fragment	K
	cartilage-derived inhibitor	EC of tumors		J
20	β -Cyclodextrin tetradecasulfate	tumors, inflammation		C
	fumagillin and analogs	tumors, inflammation		E
	Interferon- α	EC of tumors		K
	Interferon- γ	EC of tumors		E
	interleukin-12	EC of tumors		E
25	linomide	tumors, inflammation		A
	medroxyprogesterone	EC of tumors		K
	metalloproteinase inhibitors	EC of tumors		K
	pentosan polysulfate	EC of tumors		K
30	platelet factor 4	EC of tumors		M
	Somatostatin	EC of tumors		K

Suramin	EC of tumors		K
Taxol	EC of tumors		K
thalidomide	EC of tumors		K
Thrombospondin	EC of tumors		K

5

Vectors comprising angiogenic factors

	Vector type	Target	Comments/areas of use	Ref
10	acidic fibroblast growth factor	EC of tumors		K
	adenosine	EC of tumors		K
	Angiogenin	EC of tumors		K
	Angiotensin II	EC of tumors		K
15	basement membrane components	tumors	e.g., tenascin, collagen IV	M
	basic fibroblast growth factor	EC of tumors		K
	Bradykinin	EC of tumors		K
20	Calcitonin gene-related peptide	EC of tumors		K
	epidermal growth factor	EC of tumors		K
	Fibrin	tumors		K
	Fibrinogen	tumors		K
	Heparin	EC of tumors		K
25	histamine	EC of tumors		K
	hyaluronic acid or fragments thereof	EC of tumors		K
	Interleukin-1 α	EC of tumors		K
	laminin, laminin fragments	EC of tumors		K
30	nicotinamide	EC of tumors		K
	platelet activating factor	EC of tumors		K

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5	Platelet-derived endothelial growth factor	EC of tumors		K
	prostaglandins E1, E2	EC of tumors		K
	spermine	EC of tumors		K
	spermine	EC of tumors		K
	Substance P	EC of tumors		K
10	transforming growth factor- α	EC of tumors		K
	transforming growth factor- β	EC of tumors		K
	Tumor necrosis factor- α	EC of tumors		K
	vascular endothelial growth factor/vascular permeability factor	EC of tumors		K
	vitronectin			A

- 15 Vector molecules other than recognized angiogenetic factors with known affinity for receptors associated with angiogenesis

	Vector type	Target	Comments/areas of use	Ref
20	angiopoietin	tumors, inflammation		B
	α_2 -antiplasmin	tumors, inflammation		
	combinatorial libraries, compounds from	tumors, inflammation	for instance: compounds that bind to basement membrane after degradation	
25	endoglin	tumors, inflammation		D
	endosialin	tumors, inflammation		D
	endostatin [collagen fragment]	tumors, inflammation		M

5	Factor VII related antigen	tumors, inflammation		D
	fibrinopeptides	tumors, inflammation		ZC
	fibroblast growth factor, basic	tumors, inflammation		E
	hepatocyte growth factor	tumors, inflammation		I
	insulin-like growth factor	tumors, inflammation		R
10	interleukins	tumors, inflammation	e.g., : IL-8	I
	leukemia inhibitory factor	tumors, inflammation		A
	metalloproteinase inhibitors	tumors, inflammation	e.g., batimastat	E
15	Monoclonal antibodies	tumors, inflammation	for instance: to angiogenetic factors or their receptors, or to components of the fibrinolytic system	
20	peptides, for instance cyclic RGD _n FV	tumors, inflammation		B,Q
	placental growth factor	tumors, inflammation		J
	placental proliferin-related protein	tumors, inflammation		E
	plasminogen	tumors, inflammation		M
	plasminogen activators	tumors, inflammation		D

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5	plasminogen activator inhibitors	tumors, inflammation		U,V
	platelet activating factor antagonists	tumors, inflammation	inhibitors of angiogenesis	A
	platelet-derived growth factor	tumors, inflammation		E
	pleiotropin	tumors, inflammation		ZA
	proliferin	tumors, inflammation		E
10	proliferin related protein	tumors, inflammation		E
	selectins	tumors, inflammation	e.g., E-selectin	D
	SPARC	tumors, inflammation		M
15	snake venoms (RGD-containing)	tumors, inflammation		Q
	Tissue inhibitor of metalloproteinases	tumors, inflammation	e.g., TIMP-2	U
	thrombin	tumors, inflammation		H
20	thrombin-receptor-activating tetradecapeptide	tumors, inflammation		H
	thymidine phosphorylase	tumors, inflammation		D
	tumor growth factor	tumors, inflammation		ZA

Receptors/targets associated with angiogenesis

	Vector type	Target	Comments/areas of use	Ref
	biglycan	tumors, inflammation	dermatan sulfate proteoglycan	X
5	CD34	tumors, inflammation		L
	CD44	tumors, inflammation		F
	collagen type I, IV, VI, VIII	tumors, inflammation		A
	decorin	tumors, inflammation	dermatan sulfate proteoglycan	Y
10	dermatan sulfate proteoglycans	tumors, inflammation		X
	endothelin	tumors, inflammation		G
	endothelin receptors	tumors, inflammation		G
	fibronectin	tumors		P
15	Flk-1/KDR, Flt-4	tumors, inflammation	VEGF receptor	D
	FLT-1 (fms-like tyrosine kinase)	tumors, inflammation	VEGF-A receptor	O
	heparan sulfate	tumors, inflammation		p
20	hepatocyte growth factor receptor (c-met)	tumors, inflammation		I
	insulin-like growth factor/mannose-6- phosphate receptor	tumors, inflammation		R

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5	integrins: β_3 and β_5 , integrin $\alpha_v\beta_3$, integrin $\alpha_6\beta_1$, , integrins α_6 , integrins β_1 , integrin $\alpha_2\beta_1$, integrin $\alpha_v\beta_3$, integrin α_5	Tumors, inflammation	laminin receptor	D, P
10	integrin $\alpha_v\beta_5$, fibrin receptors.		subunit of the fibronectin receptor	
15	Intercellular adhesion molecule-1 and -2	tumors, inflammation		P
	<i>Jagged</i> gene product	tumors, inflammation		T
	Ly-6	tumors, inflammation	a lymphocyte activation protein	N
	matrix metalloproteinases	tumors, inflammation		D
20	MHC class II	tumors, inflammation		
	<i>Notch</i> gene product	tumors, inflammation		T
	Osteopontin	tumors		Z
	PECAM	tumors, inflammation	alias CD31	P
	plasminogen activator receptor	tumors, inflammation		ZC
25	platelet-derived growth factor receptors	tumors, inflammation		E
	Selectins: E-, P-	tumors, inflammation		D

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	Sialyl Lewis-X	tumors, inflammation	blood group antigen	M
5	stress proteins: glucose regulated, heat shock families and others	tumors, inflammation	molecular chaperones	
	syndecan	tumors, inflammation		T
	thrombospondin	tumors, inflammation		M
	TIE receptors	tumors, inflammation	tyrosine kinases with Ig- and EGF-Iike domains	E
	tissue factor	tumors, inflammation		Z
10	tissue inhibitor of metalloproteinases	tumors, inflammation	e.g., TIMP-2	U
	transforming growth factor receptor	tumors, inflammation		E
15	urokinase-type plasminogen activator receptor	tumors, inflammation		D
	Vascular cellular adhesion molecule (VCAM)	tumors, inflammation		D
20	Vascular endothelial growth factor related protein	tumors, inflammation		
	Vascular endothelial growth factor-A receptor	tumors, inflammation		K
25	von Willebrand factor- related antigen	tumors, inflammation		L

Oligonucleotide vectors

	Vector type	Target	Comments/areas of use	Ref
5	Oligonucleotides complementary to repeated sequences, e.g. genes for ribosomal RNA, Alu-sequences	DNA made available by necrosis	Tumours Myocardial infarction All other diseases that involves necrosis	51
10				
15	Oligonucleotides complementary to disease-specific mutations (e.g. mutated oncogenes).	DNA made available by necrosis in a region of the relevant disease	Tumours	51
20	Oligonucleotides complementary to DNA of infecting agent.	DNA of infective agent	Viral or bacterial infections	51
25	Triple or quadruple-helix forming oligonucleotides	As in above examples	As in above examples	51
30	Oligonucleotides with recognition sequence for DNA-or RNA-binding proteins	DNA-binding protein, e.g. transcription factors (often overexpressed/activated in tumours or activated endothelium/immune cells	Tumours Activated endothelium Activated immune cells	

Modified oligonucleotide vectors

	Vector type	Target	Comments/areas of use	Ref
5	Phosphorothioate oligos	As for unmodified oligos	As for unmodified oligos	51
	2'-O-methyl substituted oligos	"	"	51
	circular oligos	"	"	51
10	oligos containing hairpin structure to decrease degradation	"	"	51
15	oligos with terminal phosphorothioate	"	"	51
	2'-fluoro oligos	"	"	51
20	2'-amino oligos	"	"	51
	DNA-binding drugs conjugated to oligos (for examples, see below)	"	Increased binding affinity as compared to pure oligos	52
25	Peptide Nucleic Acids (PNAs, oligonucleotidss with a peptide backbone)	"	Increased binding affinity and stability compared to standard oligos.	53
30				

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Nucleoside and nucleotide vectors

Vector type	Target	Comments/areas of use	Ref
5 Adenosine or analogues	Adenosine receptors	Vessel wall Heart	54
ADP, UDP, UTP and others	Various nucleotide receptors	Many tissues, e.g. brain, spinal cord, kidney, spleen	55

10 Receptors comprising DNA-binding drugs

Vector type	Target	Comments/areas of use	Ref
15 acridine derivatives distamycin netropsin actinomycin D echinomycin bleomycin etc.	DNA made available by necrosis	Tumours, Myocardial infarction and all other diseases involving necrosis or other processes liberating DNA from cells	

20

Receptors comprising protease substrates

Vector type	Target	Comments/areas of use	Ref
25 Peptidic or non-peptidic substrates	Cathepsin B	Tumours, a variety of which may more or less specifically overexpress proteases of various kinds, e.g. Cathepsin B	10

30

Receptors comprising protease inhibitors

	Vector type	Target	Comments/areas of use	Ref
5 10	Peptidic or non-peptidic inhibitors e.g. N-acetyl-Leu-Leu-norleucinal	Cathepsin B	Tumours, a variety of which may more or less specifically overexpress proteases of various kinds, e.g. Cathepsin B	10
15	bestatin ([(2S,3R) -3-Amino-2-hydroxy-4-phenyl-butanoyl]-L-leucine hydrochloride)	Aminopeptidases	Tumours, e.g. on cell surfaces	
20	Pefabloc (4-(2-aminoethyl)-benzenesulfonyl fluoride hydrochloride)	Serine proteases	Tumours, vessel wall etc.	
25	Commercially available inhibitors e.g. kaptopril enalapril ricionopril	Angiotensin converting enzyme	Endothelial cells	
30	Low specificity non-peptidic compounds	Coagulation factors	Vessel wall injury, tumours, etc.	
35	Protease nexins (extracellular protease inhibitors)	proteoglycans		56

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Antithrombin	proteoglycans, Coagulation factors		57
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Vectors from combinatorial libraries

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Vector type	Target	Comments/areas of use	Ref
Antibodies with structure determined during generation process	Any of above targets - or may be unknown when make functional selection of vector binding to chosen diseased structure	Any diseased or normal structure of interest, e.g. thrombi, tumours or walls of myocardial vessels	58, 59, 60
Peptides with sequence determined during generation process	"	"	58, 59, 60
Oligonucleotides with sequence determined during generation process	"	"	58, 59, 60
Modifications of oligos obtained as above	"	"	58, 59, 60

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5	Other chemicals with structure determined during generation process	"	"	58, 59, 60
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Carbohydrate vectors

10	Vector type	Target	Comments/areas of use	Ref
	neo-glycoproteins	macrophages	general activation/inflammation	
15	oligosaccharides with terminal galactose	Asialo-glycoprotein receptor	liver	61
	Hyaluronan	aggrecan (a proteoglycan) "link proteins" cell-surface receptors: CD44		62
	Mannose		Blood brain barrier, Brain tumours and other diseases causing changes in BBB	63
20	Bacterial glycopeptides		"	64

(Glyco)Lipid vectors

25	Vector type	Target	Comments/areas of use	Ref
	GM1 gangliosides	cholera bacteria in the gastrointestinal tract	diagnosis/treatment of cholera	

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5	platelet activating factor (PAF) antagonists	PAF receptors	diagnosis of inflammation	
	Prostoglandin antagonists of inflammation	Prostoglandin receptors	diagnosis of inflammation	
	Thromboxane antagonists of inflammation	Leukotriene receptors	diagnosis of inflammation	

Small molecule vectors

15	Vector type	Target	Comments/areas of use	Ref
	Adrenalin	Corresponding receptors		
	Betablockers	Adrenergic beta-receptors	Myocardium for beta-1 blockers	
	Alpha-blockers	Adrenergic alpha-receptors	Vessel wall	
	benzodiazepines			
20	serotonin-analogues	Serotonin-receptors		
	anti-histamines	Histamine-receptors	Vessel wall	
	Acetyl-choline receptor antagonists	ACh-receptors		
25	verapamil	Ca ²⁺ -channel blocker	Heart muscle	
	nifedipin	Ca ²⁺ -channel blocker	Heart muscle	

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	Amiloride	Na ⁺ /H ⁺ -exchanger	Blocks this exchanges in kidney and is generally upregulated in cells stimulated by growth factors.	
	Digitalis glycosides	Na ⁺ /K ⁺ -ATP-ases	myocardium peripheral vasculature, central nervous system	
5	Thromboxane/ Prostaglandin receptor antagonists or agonists	Thromboxane/ prostaglandin receptors	Vessel wall, Endothelium	
	Glutathione	Glutathione- receptors Leukotriene- receptors	Lung, Brain	
10	Biotin	biotin transport protein on cell surface		65
	Folate	folate transport protein on cell surface	Tumours	66
	Riboflavin	riboflavin transport protein on cell surface		67

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The following non-limitative examples serve to illustrate the invention. Confirmation of the microparticulate nature of products is performed using microscopy as described in WO-A-9607434. Ultrasonic transmission measurements may be made using a broadband transducer to indicate microbubble suspensions giving an increased sound beam attenuation compared to a standard. Flow cytometric analysis of products can be used to confirm attachment of macromolecules thereto. The ability of targeted microbubbles to bind specifically to cells expressing a target may be studied *in vitro* by microscopy and/or using a flow chamber containing immobilised cells, for example employing a population of cells expressing the target structure and a further population of cells not expressing the target. Radioactive, fluorescent or enzyme-labelled streptavidin/avidin may be used to analyse biotin attachment.

Example 1 - Adhesion of poly-L-lysine-coated
phosphatidylserine-encapsulated microbubbles to
endothelial cells

5 Poly-L-lysine (8 mg) having a molecular weight of 115
kDa was dissolved in water (400 μ l). Freshly
redispersed microbubbles of phosphatidylserine-
encapsulated perfluorobutane (40 μ l) were incubated in
10 either water (400 μ l) or the poly-L-lysine solution for
15 minutes at room temperature. Zeta potential
measurements confirmed that the poly-L-lysine-coated
microbubbles were positively charged while the uncoated
bubbles were negatively charged. A cell adhesion study
using human endothelial cells grown in culture dishes
15 was performed with the above-described microbubbles, the
uncoated microbubbles being used as a control.
Microscopy of the endothelial cells after incubation
showed a much increased number of poly-L-lysine-coated
microbubbles adhering to endothelial cells in comparison
20 to the uncoated microbubbles.

Example 2 - Gas-filled microbubbles comprising
phosphatidylserine and RGDC-Mal-PEG₃₄₀₀-DSPE

25

a) Synthesis of Boc-NH-PEG₃₄₀₀-DSPE (t-butyl carbamate
poly(ethylene glycol)distearoylphosphatidyl-
ethanolamine)

30 DSPE (distearoylphosphatidylethanolamine) (31 mg, Sygena
Inc.) was added to a solution of Boc-NH-PEG₃₄₀₀-SC (t-
butyl carbamate poly(ethylene glycol)-succinimidyl
carbonate) (150 mg) in chloroform (2 ml), followed by
triethylamine (33 μ l). The mixture formed a clear
35 solution after stirring at 41 °C for 10 minutes. The
solvent was rotary evaporated and the residue taken up
in acetonitrile (5 ml). The thus-obtained dispersion

was cooled to 4 °C and centrifuged, whereafter the solution was separated from the undissolved material and evaporated to dryness. The structure of the resulting product was confirmed by NMR.

5

b) Synthesis of H₂N-PEG₃₄₀₀-DSPE (amino-poly(ethylene glycol)-distearoylphosphatidylethanolamine)

10 Boc-NH-PEG₃₄₀₀-DSPE (167 mg) was stirred in 4 M hydrochloric acid in dioxane (5 ml) for 2.5 hours at ambient temperature. The solvent was removed by rotary evaporation and the residue was taken up in chloroform (1.5 ml) and washed with water (2 x 1.5 ml). The organic phase was removed by rotary evaporation. TLC
15 (chloroform/methanol/water 13:5:0.8) gave the title product with R_f = 0.6; the structure of the product, which was ninhydrin positive, was confirmed by NMR.

20 c) Synthesis of Mal-PEG₃₄₀₀-DSPE (3-maleimidopropionate poly(ethylene glycol)distearoylphosphatidylethanolamine)

A solution of N-succinimidyl-3-maleimidopropionate (5.6 mg, 0.018 mmol) in tetrahydrofuran (0.2 ml) is added to
25 H₂N-PEG₃₄₀₀-DSPE (65 mg, 0.012 mmol) dissolved in tetrahydrofuran (1 ml) and 0.1 M sodium phosphate buffer pH 7.5 (2 ml). The reaction mixture is heated to 30 °C and the reaction is followed to completion by TLC, whereafter the solvent is evaporated.

30

d) Synthesis of RGDC-Mal-PEG₃₄₀₀-DSPE

Mal-PEG₃₄₀₀-DSPE (0.010 mmol) in 0.1 M sodium phosphate buffer having a pH of 7.5 is added to the peptide RGDC
35 (0.010 mmol). The reaction mixture is heated to 37 °C if necessary and the reaction is followed by TLC to completion, whereafter the solvent is removed.

e) Preparation of gas-filled microbubbles encapsulated by phosphatidylserine and RGDC-Mal-PEG₃₄₀₀-DSPE

To a mixture (5 mg) of phosphatidylserine (90-99.9 mol%)
5 and Mal-PEG₃₄₀₀-DSPE (10-0.1mol%) is added 5% propylene glycol-glycerol in water (1 ml). The dispersion is heated to not more than 80 °C for 5 minutes and then cooled to ambient temperature. The dispersion (0.8 ml) is then transferred to a vial (1 ml) and the head space
10 is flushed with perfluorobutane. The vial is shaken in a cap-mixer for 45 seconds, whereafter the sample is put on a roller table. After centrifugation the infranatant is exchanged with 0.1 M sodium phosphate buffer having a pH of 7.5. The peptide RGDC, dissolved in 0.1 M sodium
15 phosphate buffer having a pH of 7.5, is added to the washed microbubbles, which are placed on the roller table. The washing procedure is then repeated.

f) Alternative preparation of gas-filled microbubbles encapsulated by phosphatidylserine and RGDC-Mal-PEG₃₄₀₀-DSPE

To phosphatidylserine (5 mg) is added 5% propylene glycol-glycerol in water (1 ml). The dispersion is
25 heated to not more than 80 °C for 5 minutes and then cooled to ambient temperature. The dispersion (0.8 ml) is transferred to a vial (1 ml) and the head space is flushed with perfluorobutane. The vial is shaken in a cap-mixer for 45 seconds, whereafter the sample is put
30 on a roller table. After centrifugation the infranatant is exchanged with 0.1 M sodium phosphate buffer having a pH of 7.5. RGDC-Mal-PEG₃₄₀₀-DSPE dissolved in 0.1 M sodium phosphate buffer having a pH of 7.5 is added to the washed microbubbles, which are then placed on the
35 roller table. The washing procedure is repeated following incorporation of the RGDC-Mal-PEG₃₄₀₀-DSPE into the microbubble membranes.

Example 3 - Gas-filled microbubbles encapsulated with
phosphatidylserine, phosphatidylcholine and biotin-
amidocaproate-PEG₃₄₀₀-Ala-cholesterol

5

a) Synthesis of Z-Ala-cholesterol (3-O-(carbobenzyloxy-
L-alanyl)cholesterol)

Cholesterol (4 mmol), Z-alanine (5 mmol) and
10 dimethylaminopyridine (4 mmol) were dissolved in
dimethylformamide/tetrahydrofuran (20 ml + 5 ml) and
dicyclohexylcarbodiimide was added. The reaction
mixture was stirred at ambient temperature overnight.
Dicyclohexylurea was filtered off and the solvent was
15 rotary evaporated. The residue was taken up in
chloroform, undissolved dicyclohexylurea was filtered
off and the solvent was removed by rotary evaporation.
The residue was placed on a column of silica gel, and Z-
Ala-cholesterol was eluted with toluene/petroleum ether
20 (20:2) followed by toluene/diethyl ether (20:2). The
fractions containing the title compound were combined
and the solvent was removed by rotary evaporation. The
structure of the product was confirmed by NMR.

25 b) Synthesis of Ala-cholesterol (3-O-(L-alanyl)-
cholesterol)

Z-Ala-cholesterol (0.48 mmol) is placed in
tetrahydrofuran (20 ml) and glacial acetic acid (3 ml)
30 and hydrogenated in the presence of 5 % palladium on
charcoal for 2 hours. The reaction mixture is filtered
and concentrated *in vacuo*.

c) Synthesis of Boc-NH-PEG₃₄₀₀-Ala-cholesterol

Ala-cholesterol is added to a solution of Boc-NH-PEG₃₄₀₀-SC (t-butyl carbamate poly(ethylene glycol)-succinimidyl carbonate) in chloroform, followed by
5 triethylamine. The suspension is stirred at 41 °C for 10 minutes. The crude product is purified by chromatography.

10 d) Synthesis of H₂N-PEG₃₄₀₀-Ala-cholesterol

Boc-NH-PEG₃₄₀₀-Ala-cholesterol is stirred in 4 M hydrochloric acid in dioxane for 2.5 hours at ambient temperature. The solvent is removed by rotary
15 evaporation and the residue is taken up in chloroform and washed with water. The organic phase is rotary evaporated to dryness. The crude product may be purified by chromatography.

20 e) Synthesis of biotinamidocaproate-PEG₃₄₀₀-Ala-cholesterol

A solution of biotinamidocaproate N-hydroxysuccinimide ester in tetrahydrofuran is added to H₂N-PEG₃₄₀₀-Ala-cholesterol dissolved in tetrahydrofuran and 0.1 M
25 sodium phosphate buffer having a pH of 7.5 (2 ml). The reaction mixture is heated to 30 °C and the reaction is followed to completion by TLC, whereafter the solvent is evaporated.

30

f) Preparation of gas-filled microbubbles encapsulated with phosphatidylserine, phosphatidylcholine and biotinamidocaproate-PEG₃₄₀₀-Ala-cholesterol

35 To a mixture (5 mg) of phosphatidylserine and phosphatidylcholine (in total 90-99.9 mol%) and biotinamidocaproate-PEG₃₄₀₀-Ala-cholesterol (10-0.1 mol%)

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is added 5% propylene glycol-glycerol in water (1 ml). The dispersion is heated to not more than 80 °C for 5 minutes and then cooled to ambient temperature. The dispersion (0.8 ml) is then transferred to a vial (1 ml) and the head space is flushed with perfluorobutane. The vial is shaken in a cap-mixer for 45 seconds, whereafter the sample is put on a roller table. After centrifugation the infranatant is exchanged with water and the washing is repeated.

g) Alternative preparation of gas-filled microbubbles encapsulated with phosphatidylserine, phosphatidylcholine and biotinamidocaproate-PEG₃₄₀₀-Ala-cholesterol

To a mixture (5 mg) of phosphatidylserine and phosphatidylcholine is added 5% propylene glycol-glycerol in water (1 ml). The dispersion is heated to not more than 80 °C for 5 minutes and then cooled to ambient temperature. The dispersion (0.8 ml) is then transferred to a vial (1 ml) and the head space is flushed with perfluorobutane. The vial is shaken in a cap-mixer for 45 seconds, whereafter the sample is put on a roller table. After centrifugation the infranatant is exchanged with water. Biotinamidocaproate-PEG₃₄₀₀-Ala-cholesterol dissolved in water is added to the washed microbubbles, which are placed on a roller table for several hours. The washing procedure is repeated following incorporation of the biotinamidocaproate-PEG₃₄₀₀-Ala-cholesterol into the microbubble membranes.

Example 4 - Gas-filled microbubbles comprising
phosphatidylserine, phosphatidylcholine, biotin-
amidocaproate-PEG₃₄₀₀-Ala-Cholesterol and drug-cholesterol

5 a) Synthesis of drug-cholesterol

Cholesterol (4 mmol), a drug having an acid group and
dimethylaminopyridine (4 mmol) are dissolved in
dimethylformamide/tetrahydrofuran (20 ml + 5 ml) and
10 dicyclohexylcarbodiimide is added. The reaction mixture
is stirred at ambient temperature overnight.
Dicyclohexylurea is filtered off and the solvent is
rotary evaporated. The title compound is purified by
chromatography.

15

b) Preparation of gas-filled microbubbles encapsulated
with phosphatidylserine, phosphatidylcholine,
biotinamidocaproate-PEG₃₄₀₀-Ala-cholesterol and drug-
cholesterol

20

To a mixture (5 mg) of phosphatidylserine and
phosphatidylcholine (in total 90-99.9mol%) and
biotinamidocaproate-PEG₃₄₀₀-Ala-cholesterol (prepared as
in Example 3) and drug-cholesterol (in total 10-0.1mol%)
25 is added 5% propylene glycol-glycerol in water (1 ml).
The dispersion is heated to not more than 80 °C for 5
minutes and then cooled to ambient temperature. The
dispersion (0.8 ml) is transferred to a vial (1 ml) and
the head space is flushed with perfluorobutane. The
30 vial is shaken in a cap-mixer for 45 seconds whereafter
the sample is put on a roller table. After
centrifugation the infranatant is exchanged with water
and the washing is repeated.

35

Example 5 - Gas-filled microbubbles encapsulated with phosphatidylserine and thiolated-anti-CD34-Mal-PEG₃₄₀₀-DSPE

5 a) Preparation of thiolated anti-CD34 antibodies

Thiolation of anti-CD34 antibodies may be effected as described by Hansen, C.B. et al. (1995) *Biochim. Biophys. Acta* 1239, 133-144.

10

b) Preparation of gas-filled microbubbles encapsulated with phosphatidylserine and thiolated-anti-CD34-Mal-PEG₃₄₀₀-DSPE

- 15 To a mixture (5 mg) of phosphatidylserine (90-99.9mol%) and Mal-PEG₃₄₀₀-DSPE (10-0.1mol%, prepared as in Example 2) is added 5% propylene glycol-glycerol in water (1 ml). The dispersion is heated to not more than 80 °C for 5 minutes and then cooled to ambient temperature. The
- 20 dispersion (0.8 ml) is transferred to a vial (1 ml) and the head space is flushed with perfluorobutane. The vial is shaken in a cap-mixer for 45 seconds, whereafter the sample is put on a roller table. After
- 25 centrifugation the infranatant is exchanged with an appropriate buffer and coupling of the thiolated antibody to the microbubbles is performed, e.g. as described by Goundalkar, A., Ghose, T. and Mezei, M. in *J. Pharm. Pharmacol.* (1984) 36 465-66 or Hansen, C.B. et al. (1995) *Biochim. Biophys. Acta* 1239 133-144. The
- 30 microbubbles are then placed on a roller table for several hours and are washed. Flow cytometric analysis of the resulting microbubbles (employing a fluorescently labeled secondary antibody) is used to confirm attachment of the anti-CD34 antibody to the bubbles.
- 35 The ability of the bubbles to bind specifically to CD34-expressing cells is studied by microscopy employing one population of cells expressing CD34 and one population

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that do not express CD34.

Example 6 - Biotin attached to gas-filled microbubbles

5

Biotin may be attached to microbubbles in many different ways, e.g. in a similar way to that described by Corley, P. and Loughrey, H.C. in (1994) *Biochim. Biophys. Acta* 1195, 149-156. The resulting bubbles are analysed by
10 flow cytometry, e.g. by employing fluorescent streptavidin to detect attachment of biotin to the bubbles. Alternatively radioactive or enzyme-labelled streptavidin/avidin is used to analyse biotin attachment.

15

Example 7 - Gas-filled microbubbles encapsulated with distearoylphosphatidylserine and biotin-DPPE

20

To distearoylphosphatidylserine (DSPS) (22.6 mg) was added 4% propylene glycol-glycerol in water (4 ml). The dispersion was heated to not more than 80 °C for five minutes and then cooled to ambient temperature. An aqueous dispersion of biotin-DPPE (1.5 mg) in 4%
25 propylene glycol-glycerol (1 ml) was added and the sample was put on a roller table for 1-2 hours. The suspension was filled into vials and the head spaces were flushed with perfluorobutane. The vials were shaken for 45 seconds, whereafter they were put on a
30 roller table. After centrifugation for 7 minutes the infranatant was exchanged with water and the washing was repeated twice. Normal phase HPLC with an Evaporative Light Scattering Detector confirmed that the membranes of the microbubbles contained 4 mol% biotin-DPPE. The
35 mean particle diameter of the microbubbles was 4 µm measured by Coulter Counter. Ultrasound transmission measurements using a 3.5 MHz broadband transducer showed

that a particle dispersion of < 2 mg/ml gave a sound beam attenuation higher than 5 dB/cm.

5 Example 8 - Gas-filled microbubbles encapsulated with phosphatidylserine and biotinylated antibody non-covalently bound to streptavidin-Succ-PEG-DSPE

10 a) Synthesis of Succ-PEG₃₄₀₀-DSPE

NH₂-PEG₃₄₀₀-DSPE (prepared as in Example 2) is carboxylated using succinic anhydride, e.g. by a similar method to that described by Nayar, R. and Schroit, A.J. in *Biochemistry* (1985) 24, 5967-71.

15 b) Preparation of gas-filled microbubbles encapsulated with phosphatidylserine and Succ-PEG₃₄₀₀-DSPE

20 To a mixture (5 mg) of phosphatidylserine (90-99.9 mol%) and Succ-PEG₃₄₀₀-DSPE (10-0.1 mol%) is added 5% propylene glycol-glycerol in water (1 ml). The dispersion is heated to not more than 80 °C for 5 minutes and then cooled to ambient temperature. The dispersion (0.8 ml) is transferred to a vial (1 ml) and the head space is
25 flushed with perfluorobutane. The vial is shaken in a cap-mixer for 45 seconds, whereafter the sample is put on a roller table. After centrifugation the infranatant is exchanged with water and the washing is repeated. Alternatively the microbubbles may be prepared as
30 described in Example 2(f).

c) Coupling of streptavidin to gas-filled microbubbles encapsulated with phosphatidylserine and Succ-PEG₃₄₀₀-DSPE

35 Streptavidin is covalently bound to Succ-PEG₃₄₀₀-DSPE in the microbubble membranes by standard coupling methods using a water-soluble carbodiimide. The sample is

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placed on a roller table during the reaction. After centrifugation the infranatant is exchanged with water and the washing is repeated. The functionality of the attached streptavidin is analysed by binding, e.g. to fluorescently labeled biotin, biotinylated antibodies (detected with a fluorescently labeled secondary antibody) or biotinylated and fluorescence- or radioactively-labeled oligonucleotides. Analysis is performed by fluorescence microscopy or scintillation counting.

d) Preparation of gas-filled microbubbles encapsulated with phosphatidylserine and biotin non-covalently bound to streptavidin-Succ-PEG₃₄₀₀-DSPE

Microbubbles from Example 8(c) are incubated in a solution containing biotinylated vectors, e.g. biotinylated antibodies. The vector-coated microbubbles are washed as described above.

Example 9 - Gas-filled microbubbles encapsulated with phosphatidylserine and biotinylated oligonucleotide non-covalently bound to streptavidin-Succ-PEG-DSPE

a) Synthesis of Succ-PEG₃₄₀₀-DSPE

NH₂-PEG₃₄₀₀-DSPE (prepared as in Example 2) is carboxylated using succinic anhydride, e.g. by a similar method to that described by Nayar, R. and Schroit, A.J. in *Biochemistry* (1985) **24**, 5967-71.

b) Preparation of gas-filled microbubbles encapsulated with phosphatidylserine and Succ-PEG₃₄₀₀-DSPE

To a mixture (5 mg) of phosphatidylserine (90-99.9 mol%) and Succ-PEG₃₄₀₀-DSPE (10-0.1 mol%) is added 5% propylene

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glycol-glycerol in water (1 ml). The dispersion is heated to not more than 80 °C for 5 minutes and then cooled to ambient temperature. The dispersion (0.8 ml) is transferred to a vial (1 ml) and the head space is
5 flushed with perfluorobutane. The vial is shaken in a cap-mixer for 45 seconds, whereafter the sample is put on a roller table. After centrifugation the infranatant is exchanged with water and the washing is repeated. Alternatively the microbubbles may be prepared as
10 described in Example 2(f).

c) Coupling of streptavidin to gas-filled microbubbles encapsulated with phosphatidylserine and Succ-PEG₃₄₀₀-DSPE

15 Streptavidin is covalently bound to Succ-PEG₃₄₀₀-DSPE in the microbubble membraness by standard coupling methods using a water-soluble carbodiimide. The sample is placed on a roller table during the reaction. After
20 centrifugation the infranatant is exchanged with water and the washing is repeated. The functionality of the attached streptavidin is analyzed by binding, e.g. to fluorescently labeled biotin, biotinylated antibodies (detected with a fluorescently labeled secondary
25 antibody) or biotinylated and fluorescence- or radioactively-labeled oligonucleotides. Analysis is performed by fluorescence microscopy or scintillation counting.

d) Preparation of gas-filled microbubbles encapsulated with phosphatidylserine and a biotinylated oligonucleotide non-covalently bound to streptavidin-Succ-PEG₃₄₀₀-DSPE

30

Microbubbles from Example 9(c) are incubated in a
35 solution containing a biotinylated oligonucleotide. The oligonucleotide-coated bubbles are washed as described above. Binding of the oligonucleotide to the bubbles is

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detected e.g. by using fluorescent-labeled oligonucleotides for attachment to the bubbles, or by hybridising the attached oligonucleotide to a labeled (fluorescence or radioactivity) complementary oligonucleotide. The functionality of the oligonucleotide-carrying microbubbles is analysed, e.g. by hybridising the bubbles with immobilized DNA-containing sequences complementary to the attached oligonucleotide. As examples, an oligonucleotide complementary to ribosomal DNA (of which there are many copies per haploid genome) and an oligonucleotide complementary to an oncogene (e.g. ras of which there is one copy per haploid genome) may be used.

15

Example 10 - Gas-filled microbubbles encapsulated with phosphatidylserine and folate-PEG-Succ-DSPE

20

a) Preparation of folate-PEG-Succ-DSPE

Folate-PEG-Succ-DSPE is synthesised as described by Lee, R.J. and Low, P.S. in (1995) *Biochimica. Biophysica. Acta* 1233, 134-144.

25

b) Preparation of gas-filled microbubbles encapsulated with phosphatidylserine and folate-PEG-Succ-DSPE

30

To a mixture (5 mg) of phosphatidylserine (90-99.9 mol%) and folate-PEG-DSPE (10-0.1 mol%) is added 5% propylene glycol-glycerol in water (1 ml). The dispersion is heated to not more than 80 °C for 5 minutes and is then cooled to ambient temperature. The dispersion (0.8 ml) is transferred to a vial (1 ml) and the head space is flushed with perfluorobutane. The vial is shaken in a cap-mixer for 45 seconds, whereafter the sample is put on a roller table. After centrifugation the infranatant is exchanged with water and the washing is repeated.

35

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Alternatively the microbubbles are prepared as described in Example 2(e) or 2(f). Analysis of folate attachment may for example be done by microscopic study of the binding of the folate-containing microbubbles to cells
5 expressing different levels of folate receptors.

Example 11 - Gas-filled microbubbles encapsulated with phosphatidylserine and thiolated-anti-CD34-Mal-PEG₃₄₀₀-DSPE, thiolated-anti-ICAM-1-Mal-PEG₃₄₀₀-DSPE and thiolated-anti-E-Selectin-Mal-PEG₃₄₀₀-DSPE
10

a) Preparation of thiolated-anti-CD34 antibodies

15 Thiolation of anti-CD34 antibodies may be effected as described by Hansen, C.B. et al. in (1995) *Biochim. Biophys. Acta* 1239, 133-144.

b) Preparation of thiolated-anti-ICAM-1 antibodies
20

Thiolation of anti-ICAM-1 antibodies may be effected as described by Hansen, C.B. et al. in (1995) *Biochim. Biophys. Acta* 1239, 133-144.

c) Preparation of thiolated-anti-E-selectin antibodies
25

Thiolation of anti-E-selectin antibodies may be effected as described by Hansen, C.B. et al. in (1995) *Biochim. Biophys. Acta* 1239, 133-144.

d) Preparation of gas-filled microbubbles encapsulated with phosphatidylserine and thiolated-anti-CD34-Mal-PEG₃₄₀₀-DSPE, thiolated-anti-ICAM-1-Mal-PEG₃₄₀₀-DSPE, thiolated-anti-E-selectin-Mal-PEG₃₄₀₀-DSPE
30

35 To a mixture (5 mg) of phosphatidylserine (90-99.9 mol%) and Mal-PEG₃₄₀₀-DSPE (10-0.1 mol%, prepared as in Example

2) is added 5% propylene glycol-glycerol in water (1 ml). The dispersion is heated to not more than 80 °C for 5 minutes and is then cooled to ambient temperature. The dispersion (0.8 ml) is transferred to a vial (1 ml) and the head space is flushed with perfluorobutane. The vial is shaken in a cap-mixer for 45 seconds, whereafter the sample is put on a roller table. After centrifugation the infranatant is exchanged with an appropriate buffer, and coupling of the antibodies from Example 11(a), 11(b) and 11(c) to the microbubbles is performed, e.g. as described by Goundalkar, A., Ghose, T. and Mezei, M. in *J. Pharm. Pharmacol.* (1984) 36, 465-466 or by Hansen, C.B. et al. in (1995) *Biochim. Biophys. Acta* 1239, 133-144. The microbubbles are placed on a roller table for several hours and are then washed.

Example 12 - The peptide FNFRLKAGOKIRFGAAWEPPRARI attached to gas-filled microbubbles encapsulated with phosphatidylserine

The peptide FNFRLKAGQKIRFGAAWEPPRARI, comprising phosphatidylserine-binding and heparin-binding sections, is synthesised. The peptide is added to preformed phosphatidylserine-encapsulated perfluorobutane microbubbles and thoroughly mixed.

Example 13 - Fibronectin covalently bound to gas-filled microbubbles encapsulated with phosphatidylserine and phosphatidylethanolamine

a) Microbubbles preparation

DSPE (25 mg) and DSPE (5.0 mg) were weighed into a clean vial and 5 ml of a solution of 1.4% propylene

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glycol/2.4% glycerol was added. The mixture was warmed to 80°C for 5 minutes. The sample was cooled to room temperature and the head space was flushed with perfluorobutane gas. The vials were shaken in a cap mixer for 45 seconds and the microbubbles were twice washed with distilled water then resuspended in 0.1 M sodium borate buffer, pH 9.

b) Modification of fibronectin

Fibronectin (1.0 mg) in 5 ml 0.01 M Hepes buffer, pH 8, was added to 0.1 mmol of the crosslinker SDBP. The mixture was incubated on ice for 2 hours.

c) Microbubble modification.

To the protein solution from (b) was added the microbubble suspension from (a) and incubation was allowed to proceed for 2 hours at room temperature on a roller table. Unreacted material was removed by allowing the microbubbles to float and then replacing the buffer with 0.1 M sodium borate buffer, pH 9. This process was repeated three times.

d) In vitro analysis.

The microbubbles were tested in the *in vitro* assay detailed in Example 21. A gradual accumulation of microbubbles binding to the cells was observed.

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Example 14 - Gas-filled microbubbles encapsulated with phosphatidylserine, and 3 β -[N-(N',N'-dimethylaminoethane)carbamoyl]cholesterol

- 5 a) Synthesis of 3 β -[N-(N',N'-dimethylaminoethane)-carbamoyl]cholesterol (DC-chol) (Farhood, H., Gao, X., Barsoum, J. and Huang, L., *Anal. Biochem.* 225, 89-93 (1995))

10 To a stirred solution of 2-dimethylaminoethylamine (19.40 mg, 24:1, 0.22 mmol) and triethylamine (310 μ l, 2.23 mmol) in dichloromethane (3 ml) at room temperature was slowly added a solution of cholesteryl chloroformate (100 mg, 0.22 mmol) in 1,4-dioxane. When the reaction
15 was completed, the mixture was evaporated to dryness and the residue was purified by flash chromatography (CHCl₃/MeOH, 4:1). A white solid was obtained, yield 105 mg (95%). The structure was verified by NMR and MALDI.

- 20 b) Preparation of microbubble dispersion

Monolayer-encapsulated microbubbles containing perfluorobutane are made from a mixture of 90% phosphatidylserine and 10% (DC-chol) by weighing DSPS
25 (4.5 mg) and (DC-chol) (0.5 mg) into a 2 ml vial. 0.8 ml propylene glycol/glycerol (4%) in water was added. The solution was heated at 80°C for 5 minutes and shaken. The solution was then cooled to ambient temperature and the headspace was flushed with perfluorobutane. The
30 vial was shaken on a cap-mixer at 4450 oscillations/minute for 45 seconds and put on a roller table. The sample was washed by centrifuging at 2000 rpm for 5 minutes. The infranatant was removed by a syringe and distilled water was added to the same
35 volume. The headspace was again flushed with perfluorobutane and the sample was kept on a roller table until a homogeneous appearance was obtained. The

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washing procedure was repeated again.

5 Example 15 - Gas-filled microbubbles encapsulated with
phosphatidylserine and WEPPRARI-PE

Phosphatidylethanolamine (PE) is reacted with an
equimolar amount of the crosslinker *N*-
hydroxysuccinimidyl-2,3-dibromopropionate in a 1:1
10 mixture of dioxane and 0.02 M HEPES buffer, pH 8.0.
Following incubation for 2 hours on ice, an equimolar
amount of the heparin-binding peptide WEPPRARI is added,
the pH is brought to 9 by the addition of 0.2 M disodium
tetraborate, and the incubation is continued for 2 hours
15 at room temperature. The reaction product is purified
by chromatography. Monolayer-encapsulated microbubbles
containing perfluorobutane are made from a mixture of
80-95 % phosphatidylserine (PS) and 5-20 % of peptide-
substituted PE.

20

25 Example 16 - Gas-filled microbubbles encapsulated with
phosphatidylserine and inactivated human thrombin-Succ-
PEG₃₄₀₀-DSPE

25

a) Inactivation of human thrombin

Human thrombin was inactivated by incubation with a 20 %
molar excess of D-Phe-L-Pro-L-Arg-chloromethyl ketone in
30 0.05 M HEPES buffer, pH 8.0, at 37 °C for 30 minutes.

b) Preparation of gas-filled microbubbles encapsulated
with phosphatidylserine and Succ-PEG₃₄₀₀-DSPE

35 To a mixture (5 mg) of phosphatidylserine (90-99.9 mol%)
and Succ-PEG₃₄₀₀-DSPE (10-0.1 mol%, prepared as in Example
9(a)) was added 5% propylene glycol-glycerol in water (1

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ml). The dispersion was heated to not more than 80 °C for 5 minutes and was then cooled to ambient temperature. The dispersion (0.8 ml) was transferred to a vial (1 ml) and the head space was flushed with
5 perfluorobutane. The vial was shaken in a cap-mixer for 45 seconds, whereafter the sample was put on a roller table. After centrifugation the infranatant was exchanged with water and the washing was repeated. Alternatively the microbubbles may be prepared as
10 described in Example 2(f).

c) Preparation of gas-filled microbubbles encapsulated with phosphatidylserine and inactivated human thrombin-Succ-PEG₃₄₀₀-DSPE

15 Inactivated human thrombin was covalently bound to Succ-PEG₃₄₀₀-DSPE in the microbubbles from Example 16(b) by standard coupling methods using a water-soluble carbodiimide. The sample was placed on a roller table
20 during the reaction. After centrifugation the infranatant was exchanged with water and the washing was repeated.

25 Example 17 - Gas-filled microbubbles having methotrexate and prodrug-activating enzyme attached

a) Methotrexate attached via a peptide linker to gas-filled micrububbles

30 Methods for attaching aminoacids to the anticancer drug methotrexate (MTX) are well described in the literature (see e.g. Huennekens, F.M. (1994), TIBTECH 12, 234-239 and references therein). Instead of a single amino acid
35 a peptide may be attached to MTX using the same technology. Such a peptide may constitute a linker for the attachment of MTX to the surface of microbubbles.

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One class of such linkers comprises peptides of the general structure (MTX)-F-K/R-X-R-Z-C where X is any amino acid and Z is a hydrophobic amino acid. A specific example of such a linker is (MTX)-F-K-L-R-L-C.

5 The SH- group in the Cys-residue is employed for attachment of the MTX-peptide to the microbubbles (e.g. composed of phosphatidylserine and Mal-PEG-DSPE) using standard technology, e.g. as in Example 2. A linker of this kind is expected to be cleaved by the enzyme

10 cathepsin B which often is selectively overexpressed outside and on the surface of tumour cells (Panchal, R.G. et al. (1996), Nat. Biotechnol. 14, 852-856). Thus, the potential prodrug (MTX)-F-K/R-X-R would be liberated selectively in tumours. This prodrug can

15 further be activated to the active drug MTX by the action of carboxypeptidases, either present endogeneously in the tumour or targeted to the tumour e.g. by tumour-associated antibodies (see below).

20 b) Prodrug-activating enzyme covalently attached to the surface of gas-filled microbubbles

An example of a prodrug-activating enzyme is carboxypeptidase A (CPA), which may be conjugated to the

25 surface of microbubbles encapsulated by, for example, a mixture of phosphatidylserine and phosphatidylethanolamine, e.g. by using a 3400 Da poly(ethylene glycol) chain bearing an N-hydroxysuccinimide group at both ends (Perron, M.J. and Page, M., Br. J. Cancer 73, 281-287); the microbubbles may be prepared by standard

30 methods. Microbubbles containing CPA may be targeted to areas of pathology by incorporating a suitable targeting vector in the CPA-containing bubbles. Alternatively CPA may be attached directly to a vector (e.g. an antibody),

35 for example by the method as described above. In this latter case the CPA-vector conjugate will be attached to the surface of the microbubbles as described in Hansen,

C.B. et al. (1995) *Biochim. Biophys. Acta* 1239 133-144.
Examples of the many possible prodrug-enzyme pairs are
described in e.g. Huennekens, F.M. (1994) *TIBTECH* 12,
234-239.

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Example 18 - Gas-filled microbubbles encapsulated with
phosphatidylserine, thiolated-anti-CEA-Mal-PEG₃₄₀₀-DSPE
and the anticancer prodrug 3',5'-O-dipamitoyl-5-fluoro-
2'-deoxyuridine

10

a) Preparation of thiolated anti-CEA antibodies

Thiolation of anti-CEA antibodies may be effected as
described by Hansen, C.B. et al. in (1995) *Biochim.
Biophys. Acta* 1239, 133-144.

15

b) Preparation of gas-filled microbubbles encapsulated
with phosphatidylserine, thiolated-anti-CEA-Mal-PEG₃₄₀₀-
DSPE and the anticancer prodrug 3',5'-O-dipamitoyl-5-
fluoro-2'-deoxyuridine

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To a mixture (5 mg) of phosphatidylserine (90-99.9
mol%), Mal-PEG₃₄₀₀-DSPE (10-0.1 mol%, prepared as in
Example 2) and the anticancer prodrug 3',5'-O-
dipamitoyl-5-fluoro-2'-deoxyuridine (Mori, A. et al.
(1995) *Cancer Chemother. Pharmacol.* 35, 447-456) is
added 5% propylene glycol-glycerol in water (1 ml). The
dispersion is heated to not more than 80 °C for 5 minutes
and is then cooled to ambient temperature. The
dispersion (0.8 ml) is transferred to a vial (1 ml) and
the head space is flushed with perfluorobutane. The
vial is shaken in a cap-mixer for 45 seconds, whereafter
the sample is put on a roller table. After
centrifugation the infranatant is exchanged with an
appropriate buffer, and coupling of the antibody to the
microbubble is performed, e.g. as described by

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Goundalkar, A., Ghose, T. and Mezei, M. in *J. Pharm. Pharmacol.* (1984) 36 465-466 or by Hansen, C.B. et al. in (1995) *Biochim. Biophys. Acta* 1239 133-144. The microbubbles are placed on a roller table for several
5 hours and are then washed.

Example 19 - Gas-filled microbubbles encapsulated with phosphatidylserine, thiolated-anti-CEA-Mal-PEG₃₄₀₀-DSPE and the anticancer prodrug N-trifluoroacetyl-adriamycin-14-valerate

10

a) Preparation of thiolated anti-CEA antibodies

15 Thiolation of anti-CEA antibodies may be effected as described by Hansen, C.B. et al. in (1995) *Biochim. Biophys. Acta* 1239 133-144.

b) Preparation of gas-filled microbubbles encapsulated with phosphatidylserine, thiolated-anti-CEA-Mal-PEG₃₄₀₀-DSPE and the anticancer prodrug N-trifluoroacetyl-adriamycin-14-valerate

20

To a mixture (5 mg) of phosphatidylserine (90-99.9 mol%), Mal-PEG₃₄₀₀-DSPE (10-0.1 mol%, prepared as in
25 Example 2) and the anticancer prodrug N-trifluoroacetyl-adriamycin-14-valerate (Mori, A. et al. (1993) *Pharm. Res.* 10, 507-514), is added 5% propylene glycol-glycerol in water (1 ml). The dispersion is heated to not more
30 than 80 °C for 5 minutes and is then cooled to ambient temperature. The dispersion (0.8 ml) is transferred to a vial (1 ml) and the head space is flushed with perfluorobutane. The vial is shaken in a cap-mixer for 45 seconds, whereafter the sample is put on a roller
35 table. After centrifugation the infranatant is exchanged with an appropriate buffer, and coupling of the antibody to the microbubble is performed, e.g. as

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described by Goundalkar, A., Ghose, T. and Mezei, M. in *J. Pharm. Pharmacol.* (1984) 36 465-66 or by Hansen, C.B. et al. in (1995) *Biochim. Biophys. Acta* 1239 133-144.

5 The microbubbles are placed on a roller table for several hours and are then washed.

Example 20 - Method of use

10 An agent comprising phosphatidylserine-encapsulated microbubbles having inactivated human thrombin-Succ-PEG₃₄₀₀-DSPE incorporated into the encapsulating membrane is lyophilised from 0.01 M phosphate buffer, pH 7.4. The product is redispersed in sterile water and injected
15 intravenously into a patient with suspected venous thrombosis in a leg vein. The leg is examined by standard ultrasound techniques. The thrombus is located by increased contrast as compared with surrounding
20 tissue.

Example 21 - Preparation and biological evaluation of gas-containing microbubbles of DSPS 'doped' with a lipopeptide comprising a heparin sulphate binding
25 peptide (KRKR) and a fibronectin peptide (WOPPRARI)

This example is directed at the preparation of targeted microbubbles comprising multiple peptidic vectors arranged in a linear sequence.

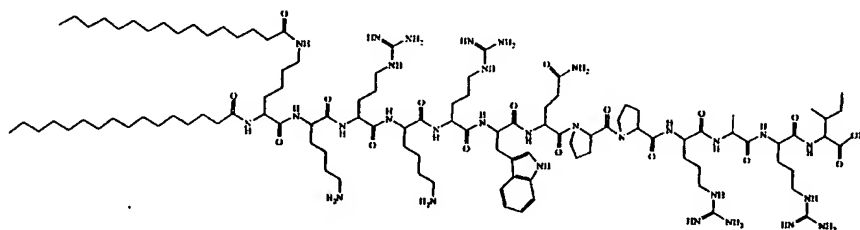
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a) Synthesis of a lipopeptide consisting of a heparin sulphate binding peptide (KRKR) and fibronectin peptide (WOPPRARI)

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The lipopeptide was synthesised on an ABI 433A automatic peptide synthesiser starting with Fmoc-Ile-Wang resin on a 0.1 mmol scale using 1 mmol amino acid cartridges. All amino acids and palmitic acid were preactivated using HBTU before coupling. The simultaneous removal of peptide from the resin and side-chain protecting groups was carried out in TFA containing 5% phenol, 5% EDT, 5% anisole and 5% H₂O for 2 hours, giving a crude product yield of 150 mg. Purification by preparative HPLC of a 40 mg aliquot of crude material was carried out using a gradient of 70 to 100% B over 40 minutes (A = 0.1% TFA/water and B = MeOH) at a flow rate of 9 ml/min. After lyophilisation, 16 mg of pure material were obtained (analytical HPLC, gradient 70-100% B where B = MeOH, A = 0.01% TFA/water: detection - UV 260 and fluorescence, Ex₂₈₀, Em₃₅₀ - product retention time = 19.44 minutes). Further product characterisation was carried out using MALDI mass spectrometry: expected M+H at 2198, found at 2199.

b) Preparation of gas-filled microbubbles of DSPS 'doped' with a multiple-specific lipopeptide consisting of a heparin sulphate binding peptide (KRKR) and fibronectin peptide (WOPPRARI)

5 DSPS (4.5 mg) and lipopeptide from (a) (0.5 mg) were weighed into each of two vials and 0.8 ml of a solution of 1.4% propylene glycol/2.4% glycerol was added to each vial. The mixtures were warmed to 80°C for 5 minutes
10 (vials shaken during warming). The samples were cooled to room temperature and the head spaces flushed with perfluorobutane gas. The vials were shaken in a cap mixer for 45 seconds and rolled overnight. The resulting microbubbles were washed several times with
15 deionised water and analysed by Coulter counter [size: 1-3 micron (87%), 3-5 micron (11.5%)] and acoustic attenuation (frequency at maximum attenuation: 3.5 MHz). The microbubbles were stable at 120 mm Hg. MALDI mass spectral analysis was used to confirm incorporation of
20 lipopeptide into DSPS microbubbles as follows: ca. 0.05-0.1 ml of microbubble suspension was transferred to a clean vial and 0.05-0.1 ml methanol was added. The suspension was sonicated for 30 seconds and the solution was analysed by MALDI MS. Positive mode gave M+H at
25 2200 (expected for lipopeptide, 2198).

c) In vitro study of gas-filled microbubbles of DSPS 'doped' with a multiple-specific lipopeptide consisting of a heparin sulphate-binding peptide (KRKR) and
30 fibronectin peptide (WOPPRARI): binding to endothelial cells under flow conditions

The human endothelial cell line ECV 304, derived from a normal umbilical cord (ATCC CRL-1998) was cultured in
35 260 mL Nunc culture flasks (chutney 153732) in RPMI 1640 medium to which L-glutamine (200 mM), penicillin/streptomycin (10,000 U/ml and 10,000 µg/ml) and 10%